Foetal circulation and ancillary sense organs of the Dromedary Camel: Architecture, Histogenesis and Histochemical observations.

By
SABAH OMER ELGOZOULI BASHIR
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SUPERVISOR: PROF. DAFALLA IBRAHIM OSMAN

DEPARTMENT OF ANATOMY
FACULTY OF VETERINARY MEDICINE
UNIVERSITY OF KHARTOUM

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Dedication

To my mother, to the soul of my father, to my son Mohammed , to my sisters….to my family.

With great love

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CONTENT

INTRODUCTION

Sudan has the second largest camel population in the world, second only to Somalia and it is estimated to be about three million camels (Salih, 1988). Tribal groups in Sudan breed distinctive types of camels (Mason and Maule, 1960). Well-known among these are the Anafi and Bishareen, prized for their racing and riding capacities, the Rashaidi, sturdy transport camels with superior drought resistance, and the large whitish Lahaween camels which give high meat yield. Over the past few decades, camels have begun to regain recognition for their food-producing potential in arid and semi-arid areas of Sudan and other countries. After having been dismissed as uneconomical domestic animals, their vital role in supporting human populations in some of the poorest and frequently drought-stricken areas of the world has now been widely acknowledged (Hjort af Ornäs, 1988).

The Arab breed of camels is well suited for meat production and transportation and camel milk is important at the subsistence level but is rarely marketed. The export of camels for slaughter, mostly to Egypt and Libyan Arab Jamahiriya and other countries, is an important source of foreign currency which should not be overlooked. Monetary returns of camel husbandry are low but, on the other hand, it is ecologically sound in long term to sustainable strategy for arid land exploitation. Scientists have presented evidence that camel grazing is beneficial for range vegetation (Gauthier-Pilters, 1984) and it appears likely that camel husbandry might discard some of the ecologically destructive effects of monocropping in sensitive environment throughout Sudan (Gauthier-Pilters, 1984).

Research on the different aspects of camels is really appreciated during recent years (Majid, 2006). Topics dealing with embryology of

domestic animals have received its due weight. Similar studies on the camel are rare and this may be due to the paucity of material. The foetal circulation of mammals have bean studied in some mammalian species and birds (Evans, 1909; Butler, 1927; Carlson, 1981; Aikawa and Kawano, 1982; Noden and de Lahunta, 1985; Coffin and Poole, 1988; Kent and Carr, 2001; McGeady, Quinn, FitzPatrick and Ryan, 2006).

The general circulation in the dromedary camel was only studied by Smuts and Hout (1987). The author did not find any information pertaining to the foetal circulation of the dromedary camel in the available literature. Therefore it has been decided to investigate the foetal circulation of the dromedary camel with the following objectives:

1. The foetal circulation (The routes of blood flow during foetal life).
2. The structure of some vessels of the foetal circulation e.g. umbilical veins and arteries, the ductus arteriosus and ductus venosus and the changes associated with their development.
3. Morphology of sensory monitors such as the carotid and aortic bodies and the carotid and aortic sinuses during prenatal development of the embryo and foetus.
4. To study the morphology of some of these changes e.g. the structure of the ligamentum arteriosum and ligamentum venosum and the changes that occur in the umbilical veins and arteries.
5. Radiographic study and vinylite injection trials to investigate the branching pattern of the umbilical arteries and veins.

CHAPTER ONE
LITERATURE REVIEW

1.1- The mammalian foetal circulation

The embryonic circulatory system can be analyzed in term of three major circulatory arcs with the heart as the common center and pumping station. One arc is entirely intraembryonic in its distribution. Its vessels distribute food material and oxygen to all parts of the growing body and return waste materials and carbon dioxide. The other two circulatory arcs have both intra-and extraembryonic components (Carlson, 1981).

The vitelline arc carries blood to and from yolk sac. The other arc carries blood to and from the allantois for gaseous interchange. As the blood from the three arcs is returned to the heart for recirculation, it is constantly being mixed so that its food material, oxygen and waste products are maintained at a tolerable level (Carlson, 1981).

In placental mammals, radical changes in the source of food supply and basic living conditions occur. In mammalian embryos, the allantoic arc takes over all functions to keep the embryo alive. Maternal blood and foetal blood are brought so close together that the foetal blood can absorb food and oxygen from the maternal blood and pass its own waste materials back to the maternal circulatory system (Carlson, 1981). Blood in the mammalian foetus passes from the placenta and enters the foetus via one large umbilical vein which is found in the umbilical cord. From the umbilical vein blood goes to the liver. Most of blood continues via the ductus venosus into the posterior vena cava and finally into the right atrium (Kent and Carr,

2001), while a small amount of blood enters the liver sinusoids and then into the posterior vena cava.

From the right atrium, the greater volume of blood passes through an interatrial foramen (foramen ovale) into the left atrium bypassing a route to the lungs. From the left atrium blood is pumped to the left ventricle and then to the systemic circulation. Unoxygenated blood returned to the left atrium from the lung is a very small quantity and mixed with blood which comes in through the foramen ovale. Most of the blood returning to the right atrium from the major venous channels enters the right ventricle and pumped into the pulmonary trunk and all but a small amount of this blood is shunted away from the lungs via the ductus arteriosus into the dorsal aorta (Kent and Carr, 2001). Blood is returned to the placenta through two large umbilical arteries which are branches of the internal iliac arteries (Getty, 1975).

1.2- Embryogenesis of the foetal circulation

1.2.1- Umbilical cord

The umbilical cord is the means of connection between the foetus and the placenta. Its length at full term, as a rule, is about equal to the length of the human foetus (Gray, 1918).

It is formed by the fifth week of development and it functions throughout pregnancy to protect the vessels that connect the foetus to the placenta (Kliman, 1998).

The line of reflection between the amnion and embryonic ectoderm is oval and is known as the primitive umbilical ring. At the 5^{th} week of development in human foetuses, the following structures pass through the ring: *(a)* the connecting stalk, containing the allantois

and the umbilical vessels (two arteries and one vein) *(b)* the yolk stalk (vitelline duct) accompanied by the vitelline vessels, and *(c)* the canal connecting the intraembryonic and extraembryonic coelomic cavities in human foetus (Sadler, 1995). The yolk sac proper occupies a space in the chorionic cavity. During further development, the amniotic cavity enlarges rapidly at the expense of the chorionic cavity, and the amnion begins to envelop the connecting and yolk stalks, thereby crowding them together and causing formation of the primitive umbilical cord. Distally, the cord contains the yolk sac stalk and umbilical vessels (Sadler, 1995). More proximally, it contains some intestinal loops and remnant of the allantois, and the yolk sac is found in the chorionic cavity and connected to the umbilical cord by its stalk. At the end of the 3rd month, the amnion has expanded to such an extent that it comes in contact with the chorion, thereby obliterating the chorionic cavity. The yolk sac then usually shrinks and is gradually obliterated (Sadler, 1995).

The rudiment of the umbilical cord is represented by the tissue which connects the rapidly growing embryo with the extra -embryonic area of the ovum. Included in this tissue are the body –stalk and the vitelline duct. The former contains the allantoic diverticulum and the umbilical vessels, while the latter forms the communication between the digestive tube and the yolk sac (Gray, 1918). The body-stalk is the posterior segment of the embryonic area, and is attached to the chorion. The dorsal surface of the stalk is covered by the amnion, while its ventral surface is bounded by the extra embryonic coelom, and it is in contact with the vitelline duct and yolk sac. With the rapid elongation of the embryo and the formation of the tail fold, the body

stalk comes to lie on the ventral surface of the embryo. The cord is covered by a layer of ectoderm which is continuous with that of the amnion and its various constituents are enveloped by embryonic gelatinous tissue (jelly of Wharton). The vitelline vessels and duct, together with the right umbilical vein, undergo atrophy and disappear; and the cord, at birth, contains a pair of umbilical arteries and the left umbilical vein (Gray, 1918). In mammals, the first vessels are laid down in the area vasculosa on the surface of the yolk sac where they develop from the mesenchymal cells.

The mesoderm remains as a permanent connection between the embryo and the wall of the chorionic vesicle, and is called the body stalk (Saunders, 1982). An endodermal diverticulum from the posterior end of the future embryo pushes into the body stalk to form the allantois. The allantois and body stalk are the forerunners of the umbilical cord (Saunders, 1982).The allantois arises as a tubular diverticulum of the hindgut which grows into the extra-embryonic coelom (McGeady, 2006) and when the hind gut is developed the allantois is carried backward with it and then opens into the cloaca or terminal part of the hind gut: it grows out into the body stalk, a mass of mesoderm which lies below and around the tail end of the embryo. The diverticulum is lined by entoderm and covered by mesoderm, and in the latter are carried the allantoic or umbilical vessels (Gray, 1918). In reptiles, birds, and many mammals, the allantois becomes expanded into a vesicle which projects into the extraembryonic coelom. During further development in birds, it is seen to project to the right side of the embryo, and gradually expands and spreads over its dorsal surface as a flattened sac between the amnion and serosa, and extends in all

directions and ultimately surrounds the yolk (Gray, 1918). By the end of the third week of development, the human embryo is attached to the placenta via a connecting stalk (Kliman, 1998). At approximately 25 days, the yolk sac forms and by 28 days, at the level of the anterior wall of the embryo, the yolk sac is pinched down to a vitelline duct which is surrounded by a primitive umbilical ring (Kliman, 1998).

The early formed yolk sac is observed in the embryo of camelus bacterianus at the stage of 7 pairs of somites (at the age of 22-24 days) (Shagaev and Baptidanova, 1976). The yolk placenta is formed at the stage of 17-22 pairs of somites (at the age of 27-28 days). The yolk placenta of the camelus bacterianus is functional for a long time: during the embryonic and prefoetal period (Shagaev and Baptidanova, 1976). By the end of the 5^{th} week, the primitive umbilical ring contains a connecting stalk within which passes the allantois (primitive excretory duct), two umbilical arteries and one vein, the vitelline duct (yolk sac stalk), and a canal which connects the intra- and extra-embryonic coelomic cavities (Kliman, 1998). Occasionally residual portion of the vitelline and allantoic duct, and their associated vessels, can still be seen even in full term umbilical cords, especially if the foetal end of the cord is examined (Kliman, 1998). Skidmore, Wooding and Allen (1996) reported that the foetus of camelus dromedarius was situated in the middle of the left uterine horn between 35 and 56 days of age, but the chorion and the large allantoic sac extend early into the other uterine horn (Ghazi, Oryan, and Pourmirzaei, 1994; Skidmore ***et al***., 1996; Tibary, 1997; Sumar, 1999).

1.2.1.1- The umbilical arteries

The umbilical arteries initially arise as several pairs of ventral branches from the caudal dorsal aortae to supply the allantois. In the embryo and foetus, these arteries course cranioventrally along the urachus which is the intraembryonic stalk of the allantois, and through the umbilicus to supply the chorioallantoic membrane. The multiple roots of the umbilical arteries degenerate and a large anastomosis is formed linking each of these large vessels with the 7^{th} lumbar dorsal intersegmental artery (Noden and de Lahunta, 1985). The umbilical arteries descend in a spiral fashion in the cord around the urachus. They give off branches to the amniotic sac and terminate in the chorioallantoic membrane (McGeady, ***et al.,*** 2006).

1.2.1.2- The umbilical veins

Paired umbilical veins, which convey blood from the placenta through the umbilical cord, pass through the septum transversum and enter the sinus venosus. As a consequence of the enlargement of the developing liver, the umbilical veins become subdivided into cranial, middle and caudal segments. As the liver expands laterally, the middle portions of the umbilical veins become incorporated into the hepatic tissue and contribute to the formation of the liver sinusoids (McGeady ***et al***., 2006). The cranial segments of the left and right umbilical veins atrophy. At the umbilicus, fusion of the left and right umbilical veins occurs. The caudal segment of the right umbilical vein atrophies and, the caudal segment of the left umbilical vein enlarges and conveys oxygenated blood from the placenta to the embryonic liver (McGeady ***et al***., 2006). When they are first established, the umbilical (allantoic) veins are embedded in the lateral body walls throughout their course

from the belly stalk to the sinus venous (Carlson, 1981). These veins have their origin in the capillary vessels of the allantois and their relations are similar whether the allantois remains saccular, as in the pig, or forms only a rudimentary lumen as in man (Carlson, 1981). As the liver grows in bulk, it fuses with the lateral body wall, and where this fusion occurs, vessels develop, connecting the umbilical veins with the plexus of the vessels in the liver. Once these connections are established, the umbilical stem tends more and more to pass by way of the connections to the liver; the old channels to the sinus venosus gradually degenerate (Carlson, 1981). Meanwhile, the umbilical veins, distal to their entrance into the body, become fused with each other so that only a single vein is established in the umbilical cord. Following this fusion in the cord, the intra-embryonic part of the umbilical channel also loses its original paired condition. The right umbilical vein is abandoned as a route to the liver, and all the placental blood is returned via the left umbilical vein. Part of the right umbilical vein persists, draining the body wall (Carlson, 1981). The remnant of left umbilical vein which persists and is present in the adult as the round ligament of the liver is contained within the falciform ligament (McGeady ***et al.,*** 2006).

1.2.2 -The Ductus venosus

When first diverted into the liver, the umbilical blood stream passes via a meshwork of small anastomosing sinusoids. As the blood volume increases, it excavates a main channel through the substance of the liver known as the ductus venosus. The ductus venosus becomes confluent with the hepatic vein which drains small sinusoids in the liver, and then it joints the posterior vena cava

(Carlson, 1981). The ductus venosus is closed, in human babies, within 3 to 7 days after birth and the remnant is known as ligamentum venosum. In the guinea-pig, the ductus venosus is an intrahepatic branch of the vena umbilicalis. The ductus venosus persists up to the time of delivary in carnivores and ruminants but atrophies during gestation in horses and pigs (McGeady ***et al.,*** 2006).

1.2.3-The Ductus arteriosus

The sixth aortic arch changes its original relationship somewhat earlier than the other aortic arches. At the early stage of development, these arches extend branches from their right and left limbs toward the lungs. After these pulmonary vessels have been established, the right side of the sixth aortic arch loses communication with the dorsal aortic root and disappears. On the left, the six aortic arch retains its communication with the dorsal aortic root. The portion of this aortic arch, between the dorsal aorta and the point where the pulmonary artery is given off, is called the ductus arteriosus (Carlson, 1981). After birth, the ductus arteriosus becomes the ligamentum arteriosum.

1.2.4- The Carotid body

It is not clear to what extent the migration of cells from the neural crest, dorsal mesoderm, endoderm and epibranchial placodes contribute to the primary cell aggregate which ultimately differentiates into the carotid body (Rogers, 1965). It has previously been suggested that the cell matrix of the third aortic arch is not an ordinary mesenchyme but contains cells derived from both the epibranchial placode of the glossopharyngeal nerve (de Winiwarter, 1939; Halley, 1955; Batten, 1960) and from the endoderm (de Winiwarter, 1939). It has also been suggested that, in chordates, neural crest cells play a part

in the formation of the wall of the aortic body (Damas, 1944; Newth, 1956) and brachial arch (Halley, 1955).

Adelmann (1925), however, could not find any clear morphological evidence for the formation of mesenchyme from neural crest cells or contribution to the branchial arches from these sources in the rat.

Moreover, there is no evidence that the epibranchial placode of the glossopharyngeal nerve fuses with or proliferates toward the primordial ganglion petrosum, even though this angle advances ventrally until it just reaches the placode.

Nevertheless, one cannot overlook the possibility of a complex of cells of different origin existing at the future site of the carotid body. Whether this addition takes the form of cells which move into the ganglionic mass and lose their immediate identity or whether they form a more or less compact mass at the tip of the primordial sinus nerve, as Batten (1960) proposed in sheep, is not certain. In the rat, just as the carotid body anlage is becoming recognizably distinct from the surrounding mesenchyme, the tip of the sinus nerve encloses a group of characteristic cells. These cells were not seen to migrate down the nerve from the ganglion petrosum before this stage. A smaller group of cells on the anterior surface of the body in association with the sinus nerve has been described by Smith (1924) and Boyd (1937). Boyd (1937) did not observe migrating cells down the nerve branch in human, whereas Smith (1924) described ‘embryonic sympathetic cells’ along this branch in 15 days old embryos of rats.

Possible contributions from the glossopharyngeal nerve have been described by Kohn (1900), Rabl (1922) and Benoit (1928). It is not improbable that cells of presumptive neural origin after migration through the glossopharyngeal nerve undergo differentiation rendering them visible as small, dark cells at the site on in the vicinity of, the peripheral contact of the sinus nerve with the anlage of the carotid body. In the rat, these cells contribute to the formation of most of the cortical region of the developing carotid body (Rogers, 1965).

The small, dark cells derived from the glossopharyngeal nerve and a few cells from the sympathetic system differentiate into cells which cannot be described as neural (Rogers, 1965).

The presence of a condensation of large, pale-staining cells about the third aortic arch has prompted Rabl (1922) and Boyd (1937) to identify this with a mesenchymatous origin for the glomus cells of the carotid body. Other investigators including Smith (1924), Ochoterena (1936), Watzka (1943), Schwarz-Karsten (1944), Ito (1950) and Celestino da Costa (1955) also believe that this primary condensation is mesenchyme, but that the glomus cells are derived from invading neuroblasts. It is suggested that the small dark cells which migrate down the sinus nerve to the carotid body differentiate into cells comparable to type Π cells (de Kock, 1954) and sustentacular cells (Ross, 1959).

1.3- Anatomy

1.3.1- Umbilical cord

It contains two arteries and one vein in addition to a widely patent, thin walled allantoic duct in the horse (Whitwell, 1975; Hong, Donahue, Giles, Petrites- Murphy, Poonacha, Tramontin, Tuttle, and

Swercze, 1993). McGeady ***et al***. (2006) reported that the body of the cord in the mare and sow consists of foetal mucoid connective tissue, surrounding two umbilical arteries, two umbilical veins fused in the cord, the urachus, and the vestige of the yolk sac. The African lion has two arteries and two veins in the umbilical cord (Benirschke and Miller, 1982). The umbilical cord of the horse is long and the proximal three-fifths of the cord are surrounded by the amnion and the distal two-fifths by the allantois ((Noden and de Lahunta, 1985). In horses, dogs and cats, the umbilical cord is divided into an amniotic and allantoic portions due to the arrangement of the foetal membranes in these species (McGeady ***et al.,*** 2006). In cattle, sheep and pigs, the amnion is reflected onto the surface of the umbilical cord. In these animals, the cord is short and is cut of at birth. The umbilical cord of horses has somewhat a long portion within the amnionic cavity and a short segment in the allantoic sac (Whitwell, 1975). The umbilical cord of ruminants is short, consisting only of the allantoic stalk and blood vessels (two arteries and two veins) and is surrounded by the amnion. At 3 months of gestation, amniotic plaques develop on the amniotic and the umbilical stalk ectoderm (Noden and de Lahunta, 1985).

Morton (1961) stated that the amnion covers most of the umbilical cord of the dromedary camel foetus whereas Mohammed, (2008) stated that the amnion starts from the navel and completely surrounds the umbilical cord. Also Morton (1961) stated that the umbilical cord of the dromedary camel at full term had small amniotic pustules, measuring up to 1 cm in diameter and fine bristle-like horns up to 15 mm. in length were present close to the umbilical cord.

Fowler and Olander (1990) reported that the umbilical cord of Bactrian camel was covered with dark skin-like squamous tissue. Malas, Sulak, Gökçimen and Sari (2003) reported that there was a positive correlation between gestation age and umbilical vessel measurements.

There is a considerable variation in the length of the cord ranging between 36 and 84 cm in the thoroughbred foals, and this variation is mainly in the amniotic portion. Excessive length of the umbilical cord between 30.5 and 137.2 cm has been considered to be a cause of abortion, foetal strangulation, and foetal demise (Caslick, 1932; Whitwell, 1975).

The length of the umbilical cord varies widely among the species as shown in Table 1 (Eurell, and Frappier, 2006) and Table 2 (Benirschke and Miller, 1982). The length of the cord increases with birth and gestational age, up to time of delivery. There is a correlation between umbilical length and weight of the placenta, with a variation according to the position of the foetus. This correlation is longest in cord encirclement and unstable position and shortest in breech presentation, transverse position, and twin birth (Adinma, 1993). Skulstad, Ulriksen, Rasmussen and Kiserud (2005) stated that cord length was positively related to birth weight and weight of the placenta, but an increased length of the cord was also associated with decreasing birth weight/placenta weight ratio for male foetuses only.

In the umbilical cord, the allantoic duct is sac like structure and primarily involved in nutrition and excretion, and is webbed with blood vessels. It collects liquid waste from the embryo, as well as to exchange gases used by the embryo (Downs, 1998). The structure first

evolved in reptiles and birds as a reservoir for nitrogenous waste, but also as a means for oxygenation of the embryo. Oxygen is absorbed by the allantois through the egg shell. The allantois functions similarly in monotremes, which are egg-laying mammals (Downs, 1998).

Tibary (1997) stated that the length of the umbilical cord reaches up to 110 cm in Bactrian camel. The most well developed placenta of Bactrian camel has an umbilical cord of 63 cm long. It contains four blood vessels and a large allantoic duct. There are many usually clockwise spirals of the umbilical cord. The immature lama foetus had a few cord spirals (Fowler and Olander, 1990). The cord of llama is 30-50 cm long and 2-3cm in diameter (Fowler and Olander, 1990). The umbilical cord in the dromedary camel is confined to the amniotic sac but it contains two arteries, two veins and one urachus (Ghazi ***et al.,*** 1994).

Morton (1961) reported that the two arteries and the two veins of the umbilical cord of the dromedary camel were distally distributed over the whole inner surface of the chorion, each main artery or vein being distributed, in general, to half of the chorion.

Table 1: Umbilical cord length at birth in domestic animals (McGeady, ***et al***, 2006**).**

Spices	Umbilical cord length
Cat	Approximately one- third of length of foetus
Cow	30-40 cm
Dog	Approximately half of length of foetus
Horse	50-100 cm
Pig	20-25 cm
Sheep	20-30 cm

Table 2: Umbilical cord length, number of blood vessels and presence of spirals at birth in different species (Benirschke and Miller, 1982**).**

Animal	Length of the umbilical cord (cm)	Blood vessels	Spirals
Eastern Kiang	25-84	3-4 blood vessels	Left direction
African lion	17	2 arteries+ 2 veins	No spirals
Great Indian rhinoceros	5-6	2 arteries +one vein	Only one twist
Speke's Gazelle	15	4 blood vessels	No spirals
Alpine ibex	16	4 blood vessels	No spirals
African elephant	65-100	3-4 blood vessels	No twists
Uganda kop	13	4 blood vessels	No twists
Hippopotamus	100	3 vessels	Left lightly spiral
Domestic dog	7-8	2 arteries +one vein	Few twists
Rabbit	2	2 arteries+ one vein	

1.3.1.1- The umbilical arteries

The umbilical arteries, right and left, are large vessels which arise from the internal iliac arteries in equine, bovine, sheep, goat, dogs and pigs and pass downward and forward in the umbilical fold of the peritoneum on either side of the bladder to the umbilicus. Both arteries may arise instead from the internal iliac in the goat (Getty, 1975). Here they are incorporated with the umbilical vein and the urachus in the umbilical cord, ramify in the chorioallantois, and end as the capillaries of the foetal part of the placenta. After birth, these vessels retract with the bladder to the pelvic cavity, their lumen becomes greatly reduced and the wall thickened so that they are cord – like and are usually termed the round ligament of the bladder (Getty, 1975). The proximal portions of the umbilical arteries are retained in relatively reduced size as the hypogastric or internal iliac arteries and superior vesical arteries as in human (Sadler, 1995). The fibrous cords extending from these arteries, on either side of the urachus toward the umbilicus, represent remains of the more distal portions of the old umbilical arteries. They are known in the adult as the obliterated branches of the hypogastric arteries or as the lateral umbilical ligaments (Carlson, 1981). The segment located between the bladder and the umbilicus in the median ligament of the bladder completely degenerates, but a remnant does persist between the internal iliac artery and the bladder (Noden and de Lahunta, 1985).

1.3.1.2-The umbilical vein

The umbilical vein receives the oxygenated blood from the placenta. Its radicals converge in the horse to form a single large trunk which is separated from the other constituents of the umbilical cord on

entering the abdomen and passes forward along the abdominal floor in the free border of the falciform ligament of the liver (Sisson, 1953).

It enters the liver at the umbilical fissure and joins the portal vein, so that the blood conveyed by it passes through the capillaries of the liver before entering the posterior vena cava (Sisson, 1953). Two umbilical veins pass through most of the length of the umbilical cord of carnivores and ruminants and they joint to form the left umbilical vein before entering the body of the embryo ((Noden and de Lahunta, 1985)

In the ox and dog, some of the blood in the umbilical vein is conveyed directly to the posterior vena cava by the ductus venosus. The vessel is given off within the liver, from a venous sinus formed by the confluence of the portal and umbilical veins, and passes directly to the posterior vena cava (Sisson, 1953). In the horse and pig, the umbilical veins fuse within the amniotic part of the cord, while in other species they fuse on entering the abdominal cavity (McGeady ***et al.,*** 2006). The old course of the umbilical vein is represented in the adult by the round ligament of the liver. This ligament starts from the umbilicus and passes through the falciform ligament and the ligamentum venosum within the substance of the liver (Carlson, 1981). In the adult ox, sheep and goat, the falciform and round ligaments are absent (Nickel, Schummer and Seiferl 1973; Getty, 1975). All ligaments are present in the horse (Bradley, 1946; Getty, 1975) and man (Snell, 2000). The round ligament is absent in the dog (Sleight and Thomford, 1970) and the pig (Getty, 1975).

1, 3.2- The ductus venosus

In pups (Burton and White, 1999) the ductus venosus is a straight vessel and arises from the left main portal vein and terminates in an ampulla into which the left hepatic and phrenic veins drain. The ampulla finally joins the caudal vena cava one pup showed a direct vascular connection between the portal sinus and the vena cava (Burton and White, 1999). Kiserud (1999) reported that, the amount of blood shunted in the human foetus seems to be less (25-40%) than in the animal foetus (50%).

The diameter of the ductus venosus was 50% of the diameter of the umbilical sinus in rat foetuses, and the ductus venosus joined the left dorsal side of the inferior vena cava (Momma, Ito and Ando, 1992). The ductus venosus persists until birth in carnivores, ruminants, and primates. However, it disappears during gestation in the pig and horse (Noden and de Lahunta, 1985). After birth, in neonatal rat, the ductus venosus narrowed rapidly and was closed completely in 2 days (Momma ***et al.,*** 1992).

The ductus venosus naturally closes up during the first week of postnatal life in most full-term neonates and the functional closure occurs within minutes of birth while the morphological closure in human full term babies occur within 3 to 7 days. After it closes, the remnant of the ductus venosus is known as the ligamentum venosum (Carlson, 1981). The ligamentum venosum is attached to the left branch of the portal vein, within the porta hepatis, and often may be continuous with the ligamentum teres (Momma ***et al.,*** 1992).

1.3.3 -The ductus arteriosus

In the developing foetus, the ductus arteriosus is a shunt connecting the pulmonary artery to the aortic arch and allows most of the blood to be pumped directly from the right ventricle to the aorta and bypasses the fluid-filled foetal lungs (Zahaka and Patel, 2002). During foetal development, this shunt protects the lungs from being overloaded and allows the right ventricle to be strengthened (Zahaka and Patel, 2002). This vessel is larger than the branches of the pulmonary artery which go to the lungs, and joins the aortic arch at its left side. Constriction of the smooth muscle in the wall of the ductus arteriosus causes reduction in the blood flow.

The reduced pulmonary resistance allows more blood to flow from the pulmonary arteries to the lungs and thus the lungs deliver more oxygenated blood to the left side of the heart. This event further increases aortic pressure so that the flow of blood in the ductus arteriosus may be transiently reversed (Zahaka and Patel, 2002). In normal newborns, the ductus arteriosus is substantially closed within 12-24 hours after birth, and is completely sealed after three weeks (Zahaka and Patel, 2002).

1.3.4- The aortic bodies

The aortic bodies are small microscopic clusters of chemoreceptor tissue. Most of them lie on the surface of the aortic arch and pulmonary trunk, and there are a few on the root of the right subclavian artery (Getty, 1975). They lie close to the aorta between the angle of the subclavian and carotid arteries on the right, and near the origin of the subclavian artery on the left. The aortic bodies are derived from the neural crest (Krause and Cutt, 1994). These sites are

consistent with the principle that baroreceptor and chemoreceptor zones lie on the root of the embryonic arterial arch. The aorta arch and right subclavian arteries are derived from the fourth pair of the aortic arches while the pulmonary arteries arise from the sixth pair (Getty, 1975).

The aortic bodies are grossly ill-defined and are not much more than a clump of cells. Consequently their number and location are difficult to establish, and have been carefully studied in very few species (Comroe, 1964). The dog and cat have well developed aortic bodies, but the mouse and rat have poorly developed or no aortic bodies (Comroe, 1964). Nonidez (1937) found about 20 aortic bodies on the arch of the aorta and pulmonary trunk, and about 15 of these were scattered over the ventrocaudal aspect of these great trunks. Moreover, about half a dozen other aortic bodies lie on the dorsocrainal aspect of these large vessels. One or two more bodies were seen on the root of the right subclavian artery. Omer (2003) stated that the aortic body of the dromedary camel was located in the wall of the arch of the aorta in the origin of the right subclavian artery and pulmonary trunk. There seems to be great variation in the number and location of the aortic bodies within the same species (Smith and Hamlin, 1977).

The arterial supply to the aortic body comes from the nearest component of the systemic circulation, typically from the aorta itself. The nerve supply of the aortic bodies consists essentially of chemoreceptor afferent axons. The fibres from the aortic bodies travel through the vagus nerve, but in a few species the aortic bodies have a separate aortic nerve (King, 1999). The developing sixth aortic arch

does indeed supply a pulmonary arterial branch to aortic bodies on the pulmonary trunk, but only in the foetus or neonate, as in human fetus and neonate kitten (Comroe, 1964).

This blood supply is supplemented by branches from the systemic circulation, usually from the left coronary artery. After birth, the pulmonary arterial branch regresses completely in these species. In young kitten, there is a transitional stage between the pulmonary and systemic arterial supplies, during which the blood supply is switched to the aorta. This is achieved by an initial proliferation that occludes the pulmonary opening (Comroe, 1964). In the adult dog, the arterial supply of the aortic bodies is achieved by a small branch from the ascending aorta, while in the adult cat and man, it comes from the coronary artery, usually the left one (Comroe, 1964). Omer (2003) reported that the arterial supply of the aortic bodies of the Dromedary Camel came from the aorta itself. The venous drainage of the aortic bodies is always performed by small veins empting into the cranial vena cava, either directly or via the left costocervical vein (Comroe, 1964).

In a few mammalian species, the aortic nerve is a depressor nerve; it runs from the aortic region as an independent nerve, joins the root of the caudal laryngeal nerve and then continues centrally in the vagus (King, 1957; Bloom and Fawcett, 1962). This occurs in the rabbit, on both sides of the neck. A fully independent aortic nerve also occurs on the left side in the cat and the badger (Meles Meles) and lion (Amoroso, Belly, King and Rosenberg 1951). Grau (1943) also reported its occurrence in the pig. It is stated that, in species lacking an independent aortic nerve, the afferent fibers from the aortic bodies

are usually incorporated within the recurrent laryngeal nerve. King (1957) and Comroe (1964) referred to this nerve as semi-independent aortic nerve.

1.3.5 -The carotid bodies

The carotid body of sheep is a single mass of oval, circular or irregular shape (Molanda, 1975). In most cases, it lies on the surface of the medial termination of the common carotid artery and is situated close to or farther from one of the arteries which begin in this region.

The size of the body varies from 1.4 to 2.6 mm in diameter and it is innervated by the carotid sinus branch of the glossopharyngeal nerve and by the branches of the external carotid nerves (Molanda, 1975). The carotid bodies of human are flattened bodies, about 3 mm wide and 5 mm long, associated with the vessel wall at the bifurcation of the common carotid into internal and external carotid arteries.

These bodies are chemoreceptors sensitive to high carbon dioxide concentration, low oxygen tension and low arterial blood pH (Junqueria and Carneiro, 2005).

Omer (2003) reported that the carotid body of the one humped camel is 5.8 mm in length and 3 mm in width. It is located in a mass of loose connective tissue at the point of origin of the internal carotid artery from the common carotid artery. Its arterial supply come from the external carotid artery. The veins drained into a plexus of veins converging the surface of the carotid body, and was conveyed from the cranial pole of the carotid body by several smaller veins into one of the large venous trunks, such as the pharyngeal, laryngeal or lingual

veins. The nerve supply is provided by small nerves from the glossopharyngeal nerve (Omer, 2003).

1.3.6 -The Aortic sinus

The aortic sinuses are specialized receptors responsive to alteration in blood pressure. The vagus nerve innervates the aortic sinus. These receptors stimulate the central control centers resulting in a reflex bradycardia, dilation of the splanchnic vessel, and fall in systemic blood pressure (Banks, 1993). King (1999) reported that the aortic sinus is one of the anatomic dilations of the aorta which occurs just above the aortic valve. It is present in the wall of the arch of the aorta.

The caliber of the ascending aorta is greatest at its origin and is termed the aortic bulb. Here, it forms three pouch- like dilatations, the aortic sinuses. These correspond to the semilunar cusps of the aortic valve; the right and left coronary arteries arise from the right and left sinuses, respectively (Getty, 1975). There are three aortic sinuses: the left which gives rise to the left coronary artery; the right sinus which gives rise to the right coronary artery and the posterior sinus with no vessels. The afferent axons belonging to this sinus come from a bundle of axons known as the aortic nerve. In most mammals, this bundle or axons is burried in and supplies the arch of the aorta, and comes from the right vagus to supply the root of the right subclavian artery. In a few species, these fibres form a fully independent aortic nerve (King, 1999). The aortic sinus of the dromedary camel is located in the wall of the aorta at the origin of coronary arteries above the cusps of the aortic valve (Omer, 2003).

1.3.7- The carotid sinus

Carotid sinuses are slight dilatations of the internal carotid arteries, which contain baroreceptors that detect changes in blood pressure and relay the information to the central nervous system (Junqueira and Carneiro, 2005). The mammalian carotid sinus is the baroreceptor area of the common carotid bifurcation commonly situated at the origin of the internal carotid artery or occipital artery (Adams, 1958).

In the dromedary camel (Omer, 2003), the carotid sinus was present at the region of origin of the internal carotid artery, at the point where the internal carotid arises from the peripheral end of the common carotid artery. At this site, the sinus forms more or less a distinct dilation. Compared with the adjoining arterial walls, the wall of the sinus is soft and extremely thin (Omer, 2003). In the dromedary camel, the common carotid artery terminates by giving off patent internal carotid artery and continues as the external carotid artery. The glossopharyngeal nerve leaves the skull through the jugular foramen in the dromedary camel. Proximally, it receives a branch from the pharyngeal branch of the vagus nerve and then divides into four branches including the carotid sinus branch, to the carotid sinus, (Smuts and Hout, 1987).

1.4 -Histology

1.4.1- Umbilical cord

The allantoic portion of the umbilical cord is not a solid cord but in the form of a web of blood vessels (Whitwell, 1975). Numerous small blood vessels are also present in the umbilical cord, especially in the vicinity of the allantoic duct. The mouse allantois consists of

mesodermal tissue which undergoes vasculogenesis to form the mature umbilical arteries and veins (Downs, 1998). The human allantois is an endodermal evagination of the developing hindgut which becomes surrounded by the mesodermal connecting stalk which in turn, forms the umbilical vasculature and the human umbilical cord. Remnants of the vitelline duct may be present (Whitwell, 1975). The cord may be significantly spiraled and, in the amnionic portion, it has many very small foci of squamous metaplasia on its surface (Whitwell, 1975).

In ruminants and the horse, the umbilical cord and umbilicus are ensheathed with smooth muscle which contracts in response to stretching of the cord at parturition (Noden and de Lahunta, 1985). There are differences in the lumenal diameter and tunica media thickness of cord vessels during second and third trimesters and the full term period. There are also predictable differences in the lumenal diameter and thickness of tunica media and tunica adventitia of the umbilical vein and umbilical arteries (Malas ***et al.,*** 2003).

In the human, the umbilical cord cross-sectional area increases with advancing gestation especially during the period 20-31 weeks and remains essentially stable thereafter. The amount of Wharton's jelly increases with gestation from 20 to 32 weeks of foetal age and remains at the same level for the remaning period of pregnancy (Skulstad ***et al.,*** 2006). At mid gestation, about 70% of the cord cross-sectional area was occupied by Wharton's jelly while at 31 weeks and later this value was reduced to 60% (Skulstad ***et al***., 2006). Wharton's jelly of the placenta or umbilical cord is a gelatinous connective tissue

composed mainly of myofibroblast-like stromal cells, collagen fibers, and proteoglycans.

Matrix cells from Wharton's jelly have recently been identified as a potential source of stem cells (Hill, 2008). It has been discovered that the blood within the umbilical cord, known as cord blood, is a rich and readily available source of primitive undifferentiated stem cells (i.e.CD34+and CD38-) (Simmons, Satterthwaite, Tenen and Seed, 1992). Lim, Bycon, Ryu, Jeong, Lee, Kim, Kang and Kweon, (2007) found that transplantation of the umbilical cord blood (UCB)-derived mesenchymal stem cells (MSCs) resulted in recovery of nerve function in dogs with a spinal cord injury and may be considered as a therapeutic modality for spinal cord injury. All arteries and veins of the umbilical cord have thick muscular wall and lack a nerve supply; the horse and rabbit have sphincters in the region of the umbilical ring (Hamilton and Dow, 1962).

In the camel, the umbilical cord consists of two arteries and two veins and a large allantoic duct;. Elastic fibres were found in these blood vessels (Ghazi, ***et al***., 1994). The epithelium of the allantoic duct is transitional (urothelial) or occasionally squamous in nature (Fowler and Olander, 1990). Numerous small blood vessels are found throughout the cord substance, some with thick musculature. The umbilical cord of Bactrian camel is covered with dark skin-like squamous tissue (Fowler and Olander, 1990).

1.4.1.1- The umbilical artery

Structure of vein

The umbilical artery has an intima which consists only of endothelium and lacks an internal elastic lamina (Fawcett, 1986). The

tunica media contains a small number of elastic fibers and two thick muscular layers which are sharply demarcated. The inner layer is composed of longitudinally directed fibres and in many places these fibres form longitudinal protrusions toward both the lumen and the outer circular muscular layer (Fawcett, 1986). The extra-abdominal portion of the umbilical artery is provided with numerous oval swellings and in these regions the wall becomes thin and consists almost exclusively of circularly arranged smooth muscle fibres (Fawcett, 1986). The internal elastic lamina is frequently interrupted when associated with thickening of longitudinally orientated smooth muscle cells. Fragments of elastic laminae developed in the intima and media and both are thicker in arteries than in the vein. No external elastic laminae or distinct adventitia are found (Stehbens, Wakefied, Gilbert-Barness and Zuccollo 2005). The umbilical arteries, because of their thick muscular tunic and the ability of the lumen to dilate due to the absence of an internal elastic membrane, can function not only as tubes for conducting blood but also as organs that regulate the blood flow (Minh, Gebrane-Youes, Smadja and Orcel, 1985).

1.4.1.2- The umbilical vein

Regional variations in the pattern of innervation of the intrafoetal portion of the umbilical vein are paralleled by regional differences in the construction pattern of the vessel's wall. Umbilical vein constriction is associated with reduced umbilical cord cross-sectional area and Wharton's jelly in female foetuses, but not in male foetuses (Skulstad ***et al.,*** 2006).The veins contain no valves (Sisson, 1953).

The umbilical vein can not stretch or retract because its wall is so thin but behaves as an organ to maintain the blood flow due to the presence of an inner limiting layer which prevents over-stretching (Minh ***et al.,*** 1985).

1.4.2 -The ductus venosus

At its junction with the umbilical vein, the vessel possesses a muscular sphincter which is innervated by postganglionic branches of the vagus nerve (Hamilton and Dow, 1962). However, Coceani Adeagbo, Cutz and Olley (1984) demonstrated a concentration of circularly oriented muscle fibres at the junction of the ductus with the portal sinus (the sphincter region) in lamb. Adrenergic and cholinergic fibres were visualized in both the sphincter and extra sphincter regions of the ductus venosus. Nerve fibres are confined to the adventitial layer and never form a plexus. A thin, short, membrane-like edge is present at the inner junction of the ductus venosus with the inferior vena cava in neonatal rat (Momma ***et al.,*** 1992). In the guinea-pig, the ductus venosus is an intrahepatic branch of the vena umbilicalis. No adrenergically innervated sphincter has been detected in the initial segment of the ductus venosus (Lachenmayer, 1971).

Ailamazyan, Kirillova, Polyanin, and Kogan (2003) reported that the double-layered wall of the ductus venosus in human foetuses contains elastic, collagen and argyrophilc fibres. The isthemic portion of the ductus venosus contains less smooth muscle fibres than the intrahepatic branches of the portal vein, and around the isthmus region of ductus venosus, vasa vasorum and nervi vasorum have been found. The ductal isthmus is an accumulation of smooth muscle cells as an intimal pillow which protrudes into the vascular lumen. The ductal

thickness is consistently bigger in the inlet than in the outlet. The tunica adventitia is greatest in the junction with the portal sinus and inferior vena cava than in the intrahepatic parenchyma. The wall thickness of the portal sinus and the umbilical vein is significantly higher than that of the ductal wall.

Mavrides Moscoso, Carvalho, Campbell, and Thilaganathan (2002) reported that the inlet of the ductus venosus contained a shelf which was rich in elastin, but devoid of any evidence of smooth muscle sphincter in human foetuses. The endothelial surface of the ductus venosus showed longitudinal corrugations and longitudinally arranged elastin fibres along the entire length of the ductus venosus (Mavrides ***et al.,*** 2002). A single layer of longitudinally arranged smooth muscle cells and occasional individual nerve cells are present along the entire length of the ductus venosus (Mavrides ***et al.,*** 2002). The structure of the tissue ridge at the junction of foetal sheep ductus venosus with the portal vein was described by Adeagbo, Kelsey and Coceani (2004). This structure is a true sphincter with autonomous regulation of its muscle and the vessel wall is endowed with a noradrenergic innervation. The diameter of the ductus venosus is significantly narrower in pups born alive than stillborn individuals. The ductus venosus has no sphincter and its closure appears to be uniform along the vessel's length (Burton and White, 1999).

1.4.3- The aortic body

The structure of the aortic bodies is identical to that of the carotid bodies (Nonidez, 1937). The aortic bodies are chemoreceptors which regulate circulation, while the Paraaortic bodies are chromaffin cells which secrete catecholamine (Fawcett, 1986). They are scattered

in small islands in the connective tissue between the aorta and pulmonary artery, approximately at the level of the semilunar valves, and also within the subepicardial connective tissue in the sulcus coronaries, mainly along the left coronary artery. The cells of the Para aortic bodies are similar to the elements of the medulla of the adrenal glands. The cells of the Para aortic bodies are in close proximity to nerve networks and ganglion cells, and they are more highly developed in the newborn than in the adult (Fawcett, 1986). Taha and King (1986) found that there are aggregations of large pale- staining cells in the wall of the aorta and the pulmonary trunk and pulmonary arteries. These aortic-pulmonary bodies resemble those of the carotid body and have a chemoreceptor function similar to that of the carotid body. Clarke and Daly (2002) reported the presence of paraganglionic tissue in the aortic-pulmonary regions of the Marmoset but it did not show the characteristic histological features of the aortic body chemoreceptors that have been described in some non-primate mammals. The distribution of the groups of cells was extremely variable, so that it would be misleading to attempt to classify their position and they were not circumscribed by a connective tissue capsule. The cells, 10-15μm in diameter, were oval or round in shape and possessed a central nucleus and clear cytoplasm.

The aortic bodies are innervated by fibres from the vagus nerve (Banks, 1993; Gartner and Hiatt, 1997). Aortic bodies measure changes in blood pressure and the composition of arterial blood flowing via them, including the partial pressure of oxygen and carbon dioxide but not the pH. The chemoreceptors responsible for sensing changes in blood gases are called glomus cells. The glomus cells help

the body to regulate breathing when there is a decrease in the blood pH, a decrease in oxygen (PO2), or an increase in carbon dioxide (PCO2) (Gonzalez, Almaraz, Obeso, Rigual, 1994).

The histology of the aortic bodies of ruminants, dog and cat is similar to that of the carotid body. It is characterized by the presence of granular cells, sustentacular cells, afferent axonal ending and abundant capillaries and sinusoids (King, 1999). Snell (2000) reported similar findings in the aortic bodies of man.

In the dromedary camel, the chief cells of the aortic bodies were usually polygonal or round in shape and the eccentric nuclei were spherical, with a distinct nuclear membrane (Omer, 2003). The chief cells were classified into light and dark or chromophobe and chromophil cells. The light one had vacuolated, faintly eosinophilic cytoplasm. The glomus cells were more ovoid or elongated with no clearly defined cell boundaries (Omer, 2003).

1.4.4-The carotid body

The carotid bodies are enclosed by a connective tissue capsule and consist of a dense sinusoidal capillary network surrounding clusters of cells. Two cell types are present within these clusters: granular endocrine cells (type I cells or chemoreceptors cells) which contain many granules rich in catecholamine and serotonin, and sustentacular cells (type Π cells) which have few or no granules (Gonzalez ***et al.,*** 1994; Eurell and Frappier, 2006). The sustentacular cells incompletely invest several granular endocrine cells. Nonmylinated afferent and efferent nerve terminals synapse on granular endocrine cells (Eurell ***et al.,*** 2006). The carotid bodies are richly innervated by the carotid sinus branch of the glossopharyngeal

nerve and by a plexus of sympathetic components from the vagus and glossopharyngeal nerves (Fawcett, 1986). The carotid bodies are highly vascular structures with a large blood flow in relation to their small volume of parenchyma and they consist of irregular clumps of pale- staining epithelioid cells (Fawcett, 1986). These epithelioid cells (glomus cells) have large, pale nuclei and light, finely granular cytoplasm (Krause and Cutt, 1994).

The principal mass of the carotid body of the dog is made up of type 1cells and the immediately adjacent connective tissue (Clarke and Dally, 1982). Type 1 cells are arranged in close proximity to the wall of the ascending pharyngeal artery inside a mass of connective tissue with definite but irregular borders. Occasionally, type 1 cells were observed in close relation to the occipital and external carotid arteries. Caudally, and separate from the principal mass, isolated groups of periadventitial type 1 cells lie freely in the connective tissue adjacent to the internal and external carotid arteries (Clark and Dally, 1982). The carotid body of the mink is a highly vascular body enveloped by a thin fibrous capsule and sometimes is divided into lobules. It has compact structure with a general sparse stroma much like the carotid body of the cat (Haldow, 1986). In domestic fowl, the carotid body consists of a dense capsule and parenchyma; the parenchymal elements are type I cells, type Π cells, axonal endings, blood vessels, unidentified cells, collagen and non cellular elements (Abdel-Magied and Drommer, 1989). The polygonal chief or type 1 cells are loosely assembled into generally small nests by a meshwork of mostly reticulin fibres. The chief cells have a uniform appearance and small round nuclei with fine chromatin and sometimes possess a

small nucleolus. The cells may have a small amount of finely granular and faintly eosinophilic cytoplasm which is more often mostly vacuolated (Haldow, 1986). Some cell nests give a positive chromaffin reaction (Bloom and Fawcett, 1962; Haldow, 1986). At the periphery of each cell nests are a few sustentacular or type 2 cells (Haldow, 1986; Banks, 1993; King, 1999). Typically, they have elongated dark staining nuclei but otherwise are poorly defined by light microscopy. A few mast cells often occur in the stroma of the body and sometimes also in the surrounding connective tissue. Haldow (1986) found that the carotid bifurcation has small isolated clusters of chief cells in the adventitia of the regional arteries in the mink. This is also true in the rabbit (Clarke and Dally, 1981), dog (Clarke and Dally, 1982) and cat (Clarke and Dally, 1983).

The carotid body of the camel consists of lobules and each of which lobule is composed of several secondary lobules, the latter in turn consists of acinus –like structures or glomi formed by special parenchymal cells. These cells are of two types; type 1 or chief cells and type Π or sustentacular cells. The nuclei of type 1 cells are moderately stained and the chromatin is evenly distributed (Etemadi, 1975). One or two nucleolus- like structures can be seen in some nuclei. There are also some cells with round dark –staining nuclei; these cells can be interpreted as type Π cells. Each acinus is surrounded by a well-defined basement membrane (Etemadi, 1975). Dilated capillaries or rather sinusoids enter into the lobules and anastomose with each other. Small interstitial nerve branches usually consist of one or two myelinated nerve fibres accompanied by groups of several unmyelinated axons (Omer, 1998). Hussein, Al-Samarrae

and Sadik (1998) confirmed this observation and added that the basement membrane of each acinus is in close contact with the cell membrane of both cell types. The carotid bodies are sensitive to changes in pH and temperature (Gonzalez ***et al***., 1994).

1.4.5- The aortic sinus

The aortic sinus is an elastic dilation and therefore has a highly elastic wall (King, 1999). Many afferent terminals from the glossopharyngeal nerve ramify in the tunica adventitia of this structure. The vagus nerve innervates the aortic sinus (Banks, 1993; Gartner, and Hiatt, 1997; King, 1999). Omer (2003) stated that the tunica intima of the aortic sinus in the dromedary camel was greatly thickened and consisted of collagen fibres and fine elastic fibres. The tunica media was very thin and consisted of elastic tissue in the form of fenestrated membranes, while the adventitia was rich in elastic fibres in the form of lamellae.

1.4.6 -The carotid sinus

The baroreceptors of the right common carotid in the cat are characteristic structures confined to pressure –sensitive region of the adventitia (Boss and Green, 1954). Traditionally, the carotid sinus has been identified as the dilated portion of the common carotid bifurcation, although in some animals dilation may be lacking (Adams, 1958). Furthermore sensory nerve fibers are distributed in large numbers only to the carotid dilatation itself and in other confluent vascular areas of the carotid bifurcation region of some species (Rees, 1968). In all cases, the densely innervated arterial wall corresponds to the parts of the carotid bifurcation which have a high density of elastic tissue in the tunica media (Bagshaw and Fisher,

1971; Knoche**,** Wiesner, Menzel and Addicks, 1980). The arterial tunica media of the sinus is thin to allow it to respond to changes in blood pressure. The intima and the adventitia are very rich in nerve endings (Junqueira and Carneiro, 2005). Fawcett (1986) stated that the tunica media of the carotid sinus is thinner than elsewhere, while the adventitia is thicker and contains a large number of sensory nerve endings derived from the glossopharyngeal nerve; these nerve endings are stimulated by stretching.

A presumptive carotid sinus is present at the origin of the internal carotid in the dromedary camel and it is characterized by a comparatively thin vascular wall rich in elastic fibers (Abdel-Magied and Drommer, 1989). Omer (2003) reported that in Dromedary Camel, the wall of the carotid sinus showed two structural modifications: first, the endothelial cells of the intima were polygonal in shape. Secondly, the subendothelial layer was thick and consisted of collagenous and elastic fibres with longitudinal orientation. Some fibroblasts, and in the deeper portion of the intima, small bundles of smooth muscle fibres were found. The internal elastic membrane was difficult to distinguish, since the tunica media consisted principally of the elastic membranes. The tunica media was converted into elastic tissue. The adventitia was relatively thin and consisted largely of elastic and collagenous fibres and was demarcated from the surrounding connective tissue. There was no distinct external elastic lamina. The adventitia contained vasa vasorum, nerve fibres and lymphatic vessels.

CHAPTER TWO
MATERIAL AND METHODS

2.1 -Gross anatomy

Fifty foetuses, used in this study, were obtained from Elbogaa, Elsalam and Tambool slaughter houses immediately after their mothers were slaughtered.

The age of the foetuses was estimated according to two equations 1-: **Y= 0.366X - 23.99**

Depending upon Curved crown-rump length (**CVRL)**

While **X** = unknown foetal age in days from known

Y = body dimensions (cm). (Elwishy, Hemeida, Omer, Mobarak and Elsyed, 1981).

And reestimated with equation 2- : **Y= 0.324X – 24.99.** Vertebral column **(VR)**. (Elwishy, ***et al***, 1981). The two equations give the same results.

Thirty specimens were dissected either in fresh state or after fixation in 10% formalin to follow the route of blood within the embryo and measure the dimensions of the ductus venosus and ductus Arteriosus. For formalin fixation, the foetuses were washed carefully in water and then followed by injecting normal saline in the umbilical veins to remove blood in the vessels. Enough quantity of formalin was injected in the large umbilical vein till the formalin was clean when seen in the carotid arteries. After completion of fixation, the foetuses were stored in 10% formalin. These specimens were injected with radio-opaque material (Culling, 1974). Five specimens were injected with vinyl acetate (Tompsett, 1970). The fresh specimens were used for the study of the distribution of the blood vessels in the liver and to

follow the relationship between the two umbilical veins before they entered the liver and also their location in the umbilical cord till they ramified to many branches in the placenta. These specimens were used to measure the length of the ductus venosus and ductus arteriosus and to determine their location in the foetal circulation.

2.1.1 -The sensory organs of arteries

20 foetuses were used to investigate the location of these organs by dissecting the head and neck regions of the foetuses. 20 hearts of foetuses were used to study the location of the aortic body and aortic sinus. To study the blood supply of the carotid body, vinylite was injected through the common carotid artery after the vessels were fixed with 10% formalin.

2.1.2- Radio- Opaque injection masses (contrast media)

Radiography of specimens that have been injected with opaque material was performed. The specimens were treated in accordance with the method described by (Culling, 1974). Three fresh foetuses were used for the x-ray study; two in the second trimester and one in the third trimester. One foetus at the second trimester fixed with 10% formalin was also used. These foetuses were injected through the umbilical and jugular veins with normal saline to remove the blood, then injected with contrast media (Omnipaque 300 mg / ml) and radiographed with diagnostic X-ray unit (Roten Kein Zutritt Abstand 1.5 Gamma 2000), at 78 kVp and 40 mA. T-MAT G/RA film (24x30 cm) (Eastman Kodak, Rochester, NY) was used with a focus–film distance of 100 cm and exposure time of 0.025 s.

2.1.3- Preparation of vinyl acetate corrosion specimens

The purpose of this technique, in general, is to fill the blood vessels with a plastic injected mass. The blood vessels of five foetuses of different ages were washed thoroughly with normal saline and then with acetone, till most of the blood was removed. After injection with vinyl acetate via the umbilical vein, the specimen was immersed in cold water and left for 24 hours to allow the plastic material to harden. The specimens were then immersed in a concentrated solution of hydrochloric acid in a glass jar. The soft tissue in the specimen was corroded away by the acid; this usually takes between 2 and 4 days and the injected mass was thereafter exposed. After full corrosion of the specimen, it was then removed gently from the glass jar and washed carefully by means of a fine jet of water. After the specimen was cleansed, it was put in a suitable jar and covered (Tompsett, 1970). This technique was employed for the study of the details of the distribution of the blood vessels within the liver.

2.2 -Histology

Thirty foetuses of dromedary camel of different ages were used to study the histology of the umbilical cord during the three trimesters (trimester = 4 months)**.** Material for light microscopy was removed from near the naval, the middle part and near the distal end of the cord of each foetus. Specimens approximately 1 cm in thickness were prepared for paraffin embedding and serially sections stained with Haematoxylin and Eosin (Culling, 1974).

Specimens from the ductus arteriosus and ductus venosus were taken from 9 foetuses and were also processed for routine histological

technique and stained with haematoxylin and eosin according to Drury and Wallington (1980) and Culling (1974).

Special stains were also used as follows:

1. **Masson's trichrome stain (Analine blue or light green):** It is used for the differentiation between smooth muscle fibres and collagen fibres (Culling, 1974; Drury and Wallington, 1980).
2. **Van Gieson technique (1899):** It is used for the differentiation between smooth muscle fibres and collagen fibres (Bancroft, 1990).
3. **Gordon and Sweet's method for reticular fibres (Gordon and Sweet, 1936):** This method was used for the detection of reticulin fibres (collagen type ш) according to the method of Bancroft (1990).
4. **Orcein:** used for the study of elastic fibres (Culling, 1974).
5. **Aldehyde fuchsin**: used to demonstrate elastic fibres (Bancroft, 1990).
6. **Verhoeff's Haematoxylin:** used to demonstrate elastic fibres (Culling, 1974).

2.2.1- Sensory organs of the arteries

Twenty foetuses were used to study the histology of the carotid and aortic bodies and carotid and aortic sinuses. Specimens of approximately 1 cm in thickness were taken and prepared for paraffin embedding and stained with Haematoxylin and Eosin (Culling, 1974).

The following special stains were also used:

1. **Gordon and Sweet's method for reticular fibres (Gordon and Sweet, 1936).**
2. **Verhoeff's Haematoxylin.**

2.2.2 - Histometry

Histometrical measurements were carried out on transversely cut umbilical arteries, umbilical veins and the allantoic duct to determine the diameter and the wall thickness of these structures during the three trimesters.

Olympus microscope **(CH20-Japan)** filted with ocular micrometer lens **X6** was used in these measurements. The objective lenses **X4** and **X10** were used to determine the measurements after calibrating the ocular scale of the microscope (Thienpont, Rochette and Vanparijis, 1986).

Twelve measurements were taken for the wall thickness and diameter of the umbilical arteries, umbilical veins and the allantoic duct from each animal and the average was calculated at the distal, middle and proximal (near the naval) parts of the umbilical cord.

2.2.3 -Histochemistry

The material used for histochemical investigation was collected from 6 foetues (two foetuses from each trimester).

2.2.3.1- Polysaccharides

The specimens for the investigation of carbohydrates were fixed in formalin and processed for paraffin wax sections and then stained with periodic acid Schiff (PAS) technique according to the method of (Bancroft, 1990). Control sections for glycogen were treated with 0.1% malt diastase or saliva for 30 minutes at room temperature.

2.2.3.2- Enzymes

2.2.3.3- Alkaline phosphatase

Fresh frozen section were placed in Columbia jars, fixed in acetone at 4◦C and stained according to the method of Gomori and

Lillie as described by Drury and Wallington (1980). The sections were incubated at pH 9.2 for 30 minutes at 37◦C using the substrate calcium phosphate. Control sections were treated in a medium lacking the substrate.

2.2.3.4 -Acid phosphatase

Fresh frozen sections were fixed in acetone at 4◦C and stained according to the method of Gomori as described by Drury and Wallington (1980). The sections were incubated at pH 5.0 for two hours at 37◦C using the substrate lead nitrate. Control sections were treated in a medium lacking the substrate.

CHAPTER THREE
RESULTS

3.1 -The foetal circulation

In camel foetus, blood from the placenta was carried to the foetus by two large umbilical veins which emptied in intra abdominal venous sinus and one vein emerged and entered the liver. The umbilical vein was joined by the portal vein and emptied into the ductus venosus. These umbilical veins were found in the umbilical cord (Figs. 1, 2). The ductus venosus then joined the caudal vena cava intrahepatic (Fig. 3). The hepatic sinusoids joined some branches of the portal vein (Fig. 4). The lower border of the septum secundum (the crista dividens) directed the blood which entered the right atrium to pass through the foramen ovale to the left atrium and then to the left ventricle. The aorta emerged from the left ventricle and gave several aortic branches. The cranial vena cava and the coronary veins also joined the right ventricle. The pulmonary trunk emerged from the right ventricle and joined the caudal aorta through the ductus arteriosus. Two large umbilical arteries, which were branches from the caudal aorta beyond the origin of the external iliac arteries, reached the placenta where they divided into smaller branches (Fig.5).

3.2 -Gross anatomy

3.2.1 -The Umbilical cord

The umbilical cord of the dromedary camel contained four blood vessels; two arteries and two veins and a large allantoic duct and covered with the amnion (Fig. 6). The amnion had clusters of projections, white to yellowish in color, and varied in their size. The

amnion surrounded the umbilical cord in spiral bands which made the surface rough except at the first quarter near the navel which was covered with skin (Fig. 6). The length and diameter of the cord increased progressively with gestation (age). The length of the umbilical cord, during the first trimester, ranged between 5 and 11 cm with an average of 8 cm and with a diameter ranged between 7 mm and 25 mm with an average of 16 mm. During the second trimester the length varied between 14 and 31 cm with an average of 22.5 cm, while the diameter ranged between 14 mm and 27 mm with an average of 20.5 mm. The umbilical cord length during the third trimester varied from 47 to 72 cm with an average of 59.5 cm while the diameter varied between 20 mm and 30 mm with an average of 25 mm.

The blood vessels were buried within Wharton's jelly. The quantity of Wharton' jelly at the proximal part of the cord was greater than in the middle and distal parts. The allantoic duct was large in caliber at the distal part and it gradually decreased in caliber toward the navel, so that the circumference of the cord had different size which ranged between 0.5 and 1 cm within the same cord. The wall thickness of the allantoic duct, during the first trimester, varied from 0.27 mm to 0.55 mm with an average of 0.41 mm and with a diameter varied between 1.26 mm and 2.53 mm with an average of 1.89 mm. During the second trimester, the wall thickness of the allantoic duct varied between 0.78 mm and 1.1 mm with an average of 0.94 mm and the diameter varied between 2.6 mm and 3.27 mm with an average of 2.95 mm. During the third trimester the wall thickness varied between 1.05 mm and 1.3 mm with average of 1.1mm and the diameter of the

allantoic duct varied between 3.2 mm and 7.12 mm with an average of 5.02 mm.

3.2.2- The umbilical vessels

There were two veins with different sizes, and they emerged from the placenta and united, at a distance of 0.5 cm from the liver during first trimester and 8 cm during the third trimester, in a venous sinus near the liver (Fig. 7). The venous sinus was located near the abdominal wall and then became in contact with the wall during the third trimester. The large vein was situated cranially while the small vein was situated caudally to the right side of the sinus. The two veins proceeded together till they entered the abdominal cavity (Fig. 7). One foetus was found to have only one vein at the umbilical ring because the two veins merged in the cord at about 8 cm away from the navel. The cord also contained two arteries of unequal size (Fig. 8) while the two veins were almost equal in size during the first trimester. There was a spiral blood vessel surrounding the cord under the amnion before the formation of foci of squamous metaplasia on its surface which appeared during the last weeks of this trimester. The spiral blood vessel supplied the amnion.

Connective tissue surrounded the two arteries at the umbilical ring and the allantoic duct at the middle of the cord. These two arteries originated from the abdominal aorta beyond the origin of the two external iliac arteries. The big artery was found at the left side and was attached to the urinary bladder, while the small artery was found at the right side of the bladder.

The location of the umbilical veins and the umbilical arteries varied along the length of the cord. At the umbilical ring, the two veins proceeded together cranially towards the liver and the two

arteries together with the allantoic duct were situated between the veins and proceeded caudally toward the bladder. At the proximal part, the two veins were situated at the periphery of the cord and were covered with the amnion while the two arteries were found at the center of the cord near the allantoic duct (Fig. 6). At the middle part of the cord the two veins were found at one side and the two arteries at the opposite side while the allantoic duct was found at the middle of the cord (Text Fig.1).

At the distal part, one artery and one vein proceeded together toward one of the two horns of the placenta; the large vein together with the large artery proceeded toward the left horn while the small vein together with the small artery proceeded toward the right horn.

The large artery ramified to give many branches in the left horn and the large vein is formed by the union of veins which were satellites of the branches of the artery. The first branch of the large artery was small and it supplied the cranial third of the foetal part of the placenta in the left horn. This branch, after a short distance, divided into two branches, the smaller one proceeded to the apex of the cranial third whereas the large one ended at the lateral part of the cranial third of the placenta. The second branch of the large umbilical artery was large and it was divided into three branches; cranial, caudal and middle branches. The cranial branch was further divided into three branches; the smallest one supplied the apex of the foetal part of the placenta, the second one ended at the medial aspect of the cranial third of the left part of allantochorion. The third one supplied the floor of the medial third and then it was reflected to the lateral side of the medial third to supply this part and continued to end at the dorsal part of the medial third of the left side of the foetal part of the placenta.

The middle branch of the large artery supplied part of the floor of the medial third and continued to end at the caudomedial part of the cranial third of the left side of the allantochorion. The caudal branch of the large artery was divided into two branches; one of them supplied the caudal part of the medial third while the other branch supplied the lateral and dorsal part of the right side of the medial third of the left side of the foetal part of the placenta. The small umbilical artery followed the small umbilical vein and together proceeded toward the center of the right horn and they ramified into four main branches in the allantochorion.

3.2.3- The ductus venosus

The ductus venosus was a straight tubular duct which began from the union of the left main portal vein and the umbilical vein. The duct passed between the left lateral liver lobe and the papillary process of the caudate lobe, and joined the posterior vena cava at its ventral surface, caudal to the left hepatic vein. The ductus venosus was devoid of branches, and made an acute angle with the hepatic vein and the posterior vena cava and it was almost at right angle with the portal vein (Fig. 10). It consisted of three parts; middle part and two terminal parts which joined the caudal vena cava superiorly and the portal vein and the umbilical vein inferiorly.

The ductus venosus was located opposite to the portal vein and caudal to the right hepatic vein and parallel to the umbilical cord. The length and diameter of the ductus venosus increased progressively with advancing age (gestation) from about 0.5 cm in length and 0.3 cm in diameter at the first trimester to 3 cm in length and 0.5 cm in diameter during the third trimester and it was about equal to half the size of the umbilical vein (Fig. 10).

3.2.4 -The ductus arteriosus

The ductus arteriosus connected the pulmonary trunk to the aortic arch (Fig. 11). It was a straight conduit about 1 mm in length and 1 mm in diameter and a lumen of 0.5 mm in diameter during first trimester and 18 mm in length and 5mm in diameter and with a lumen of 1.5 mm in diameter during second trimester. It has a length of 20 mm, a diameter of 10 mm and a lumen of 2mm during third trimester (Fig. 12). It was devoid of branches, and it was at right angle with the pulmonary trunk and at an acute angle with the aorta. This muscular vessel was larger than the branches of the pulmonary artery which proceeded to the lungs, and joined the aortic arch at its left side. The origin of the ductus arteriosus at the pulmonary trunk projected as a tip of cone-shaped toward the aorta then the ductus arteriosus passed within the wall of the aorta for about 3 mm before they became confluent (Fig. 12).

3.2.5- The aortic body

The aortic body was located in the wall of the arch of the aorta, and there were some others bodies located at the origin of the right subclavian artery and pulmonary trunk. The arterial supply to the aortic body came from the aorta itself.

3.2.6 -The carotid body

It was in the form of a mass of connective tissue at the point of origin of internal carotid artery from the common carotid artery. The site of the carotid bodies at the bifurcation of the common carotid artery into the internal carotid and external carotid appeared in the first trimester as small series of scattered carotid bodies (7 to 9 masses) with a length ranging from 40 μm to 60 μm and it increased to reach 130 μm to 150 μm during third trimester.

3.2.7- The aortic sinus

The aortic sinus was located in the wall of aorta just above the cusps of the aortic valve at the origin of coronary arteries.

3.2.8 -The carotid sinus

During the third trimester, it was clear that the common carotid artery terminated by giving off a patent internal carotid artery and continued as the external carotid artery. The main branches of the common carotid artery included internal, external and occipital arteries. The carotid sinus was present at the origin of the internal carotid artery, at the point where the internal carotid was given off from the end of the common carotid artery (Fig. 13). The sinus was in the form of a distinct dilatation with thinner wall than the adjoining arterial wall. The diameter of the sinus was greater than that of the common carotid artery. During the first trimester the diameter of the common carotid artery varied between 1 and 2 mm while the diameter of the sinus region varied between 1.5 and 2. 6 mm. During second trimester the diameter of the common carotid artery ranged between 2 and 4 mm while the diameter of the sinus region ranged between 2. 6 and 4.7 mm. During the third trimester the diameter of the common carotid artery ranged between 5 and 6 mm while the diameter of the sinus region ranged between6 and 7 mm (Fig. 13).

Table 3: Age of the foetuses and measurements of the umbilical cord.

F. No	CVR. L. (cm)	Age (days)	Um.co.L. (cm)	Circum. (cm)
1	16	109	5	3
2	17	111	7	3.5
3	19	117	11	3.5
4	28	142	14	4
5	31	150	20	4.5
6	33	155	22	5
7	40	174	22	7
8	43	183	27	7
9	44	185	27	7
10	51	204	30	7.5
11	52	207	30	7.5
12	53	210	30	7.5
13	57	221	28	7.5
14	62	234	31	8
15	68	254	40	8
16	72	262	47	8
17	82	289	58	8
18	84	295	55	8
19	102	344	70	8
20	120	393	72	8

F. No = Number of foetus
CVR. L. = curved crown rump length
Um. co. L = Length of the umbilical cord
Circum = circumference of the umbilical cord.

Table 4: Ductus venosus length of camel foetuses of different ages.

CVRL	AGE (days)	Um. co. L (cm)	D.V.L (mm)
16	109	5	5
17	111	7	5
28	142	14	13
31	150	20	12
33	155	23	11
40	174	22	14
43	183	27	17
52	207	26	17
53	210	26	15
57	221	26	17
62	234	31	20
82	289	55	30

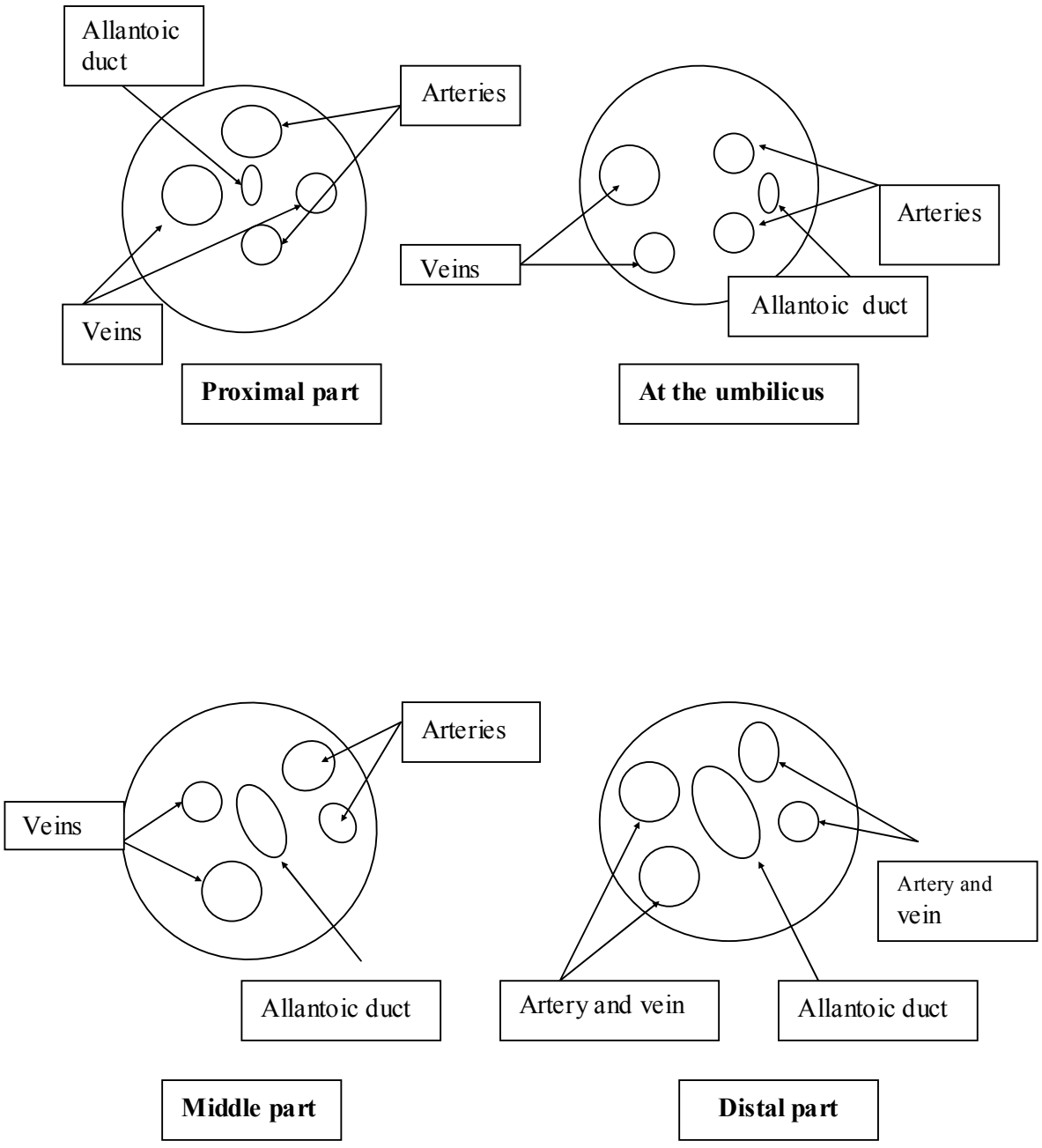
CVR. L. = Curve crown rump length
Um. co. L = umbilical cord length
D.V.L = Ductus venosus length

Table 5: Ductus arteriosus length at different age of camel foetuses

CVR. L	AGE (days)	D.A.L (mm)
13	101	2
16	109	3
17	111	3
19	117	4
28	142	6
31	150	6
43	183	5
52	207	10
53	209	11
57	221	10
62	234	12
72	262	14
81	286	14
82	289	18
84	295	18

CVR. L = Curve crown rump length
D.A.L = Ductus Arteriosus Length

Text Fig.1: Showing the location of two umbilical arteries, two umbilical veins, and allantoic duct at different parts of the umbilical cord.



3.3 -Histology

3.3.1 -First trimester

3.3.1.1 -The umbilical cord

The matrix of the cord consisted of gelatinous substance which contained mesenchymal cells with long processes and elongated nuclei and small amount of cytoplasm. Large fibroblasts with ovoid or round nuclei and granulated cytoplasm, appeared between the muscle and collagen fibres. Numerous small blood vessels were scattered in the cord and they increased in number and caliber with advancing gestation (age).

The amnion covered the cord and it contained different types of cells; polygonal cells, large scale- like cells, long cells and many degenerated cells. The allantoic portion of the umbilical cord was in the form of a web of blood vessels. Numerous small blood vessels and capillaries were seen together with a few collagen fibres, reticular and elastic fibres in the vicinity of the blood vessels. In the middle of the cord, near the allantoic duct, remnant of yolk sac was observed and was lined with flat squamous- like cells; satellite mesenchymal cells were found below them (Fig. 14). These cells disappeared during the fourth month of the first trimester. Smooth muscle fibres were arranged in bundles which were branched in the wall of arteries and veins and they were longer in the arteries than in veins but their nuclei contained more heterochromatin in the veins than in the arteries. The lumen of the veins and arteries was circumscribed.

3.3.1.2- The Umbilical Arteries

The intima consisted only of elongated endothelium lying parallel to the long axis of the vessel and the internal elastic lamina was discontinuous and thin (Fig.15). The tunica media consisted of

long smooth muscle fibres arranged in bundles which branched and anastomed. These bundles were arranged in about 20 layers with 2.6 µm in thickness at the first 12 weeks of gestation. The number of layers increased to 55 layers and the fibres were 13µm in thickness at the end of the first trimester. The muscle fibres were arranged in two layers; inner longitudinal layer and outer circular layer. A few collagen, elastic and reticular fibres were found. The external elastic lamina was absent (Fig. 15). The adventitia was composed of collagen, elastic and smooth muscle fibres and it was almost equal in size to the media. The difference in the size of the two arteries was obvious at the end of this term and the size of arteries developed faster than the veins.

3.3.1.3 -The umbilical veins

Rounded endothelium with less organization lined the intima and the internal elastic lamina was absent. The media consisted of short smooth muscle fibres arranged in bundles which were branched and had a thickness ranging from 1.3µm at the beginning of the first trimester to 7.8µm at the end of this trimester and they were arranged in two layers; inner longitudinal and outer circular layers. A few elastic, reticular and collagen fibres were also present. The size of the media increased slowly from 9 layers of smooth muscle fibres to 30 layers at end of this term. No external elastic lamina was seen. The adventitia was thicker than the media and it consisted of a few collagen, elastic, reticular and smooth muscle fibres and numerous small blood vessels (vasa vasorum). The two veins were almost equal in size at the end of this term.

During first trimester, the sinus wall was thin and consisted of three layers. The intima consisted of endothelium and a few branched

smooth muscle fibres arranged longitudinally (Fig. 16). The tunica media was small and consisted of smooth muscle and elastic fibres. The adventitia consisted of loose connective tissue rich in blood vessels, nerve fibres and smooth muscle fibers (Fig. 17).

3.3.1.4 -The allantoic duct

It consisted of three layers. The inner layer consisted of transitional epithelium with spherical cells or club-shape cells with round nuclei (Fig. 18). At the end of this term polygonal cells with round nuclei appeared under the lining epithelium, arranged in one layer and then increased gradually in thickness (Fig. 18). The middle layer consisted of connective tissue with mesenchymal cells and a few fibroblasts. This layer was equal in size to the outer layer and then it increased gradually in size with advancing gestation. There were numerous small blood vessels arranged longitudinally at the end of this term.

The outer layer contained fibroblasts and mesenchymal cells and smooth muscle and elastic fibres (Fig. 19). The smooth muscle fibres increased at the end of this term and they were arranged longitudinally, circumferentially and obliquely. Numerous small blood vessels were observed.

3.3.1.5 -The ductus venosus

The ductus venosus consisted of three layers at its two terminal ends. During first trimester, the two terminal ends consisted of endothelium of squamous cells and subendothelial layer of elongated cells with flat nuclei. Smooth muscle fibres, elastic and a few reticular fibres constituted the tunica media. The inner adventitia consisted of mesenchymal cells and fibroblasts with circular or polyhedral nuclei. The outer adventitia contained a few mesenchymal cells, fibroblasts,

elastic fibres, many fat cells and numerous blood vessels and nerve fibres (Fig. 20).

3.3.1.6-The ductus arteriosus

It was a muscular vessel consisting of three layers. The longitudinally folded intima consisted of thin endothelium and internal elastic lamina. The middle layer consisted of thin smooth muscle fibres in the form of lamellae with fine elastic fibres inbetween. The adventitia consisted of connective tissue with smooth and elastic fibres, many blood vessels and nerve fibres.

3.3.1.7- The aortic bodies

These were in the form of a cluster of cells surrounded with connective tissue containing mainly collagen fibres. Acinus-like structures with ill-defined boundaries were found. There were three types of cells; type I cells were large pale cells with large and usually eccentric nuclei and with no clear cell boundaries, type Π cells were large cells with spherical dark nuclei. The nuclei of the two types of cells possessed heterochromatin. Small dark cells with elongated nuclei were scattered among the other two types of cells.

3.3.1.8- The carotid body

The connective tissue of the wall of the internal carotid artery at the bifurcation of the common carotid artery contained a cluster of deeply stained cells with large nuclei which possessed hetero-chromatin.

3.3.1.9 -The aortic sinus

The aortic wall in this area was thick. The intima was thick and extended to the inner media and consisted of endothelium and loose subendothelial layer of fine elastic and smooth muscle fibres. The tunica media consisted of lamellae of elastic fibres, smooth muscle

fibres, small masses of nerve fibres, fibroblasts and masses of small cells with small elongated dark nuclei. These masses were not encapsulated. The adventitia was rich in fine elastic fibres, nerve fibres especially toward the coronary artery, and small blood vessels.

3.3.1.10- The carotid sinus

The lining epithelium was of simple squamous and there was thick internal elastic lamina. The tunica media consisted of about 5 lamellae of elastic and smooth muscle fibres. The adventitia was equal in size to media and consisted of connective tissue rich in cells, especially fibroblasts, and numerous nerve bundles.

3.3.2- Second trimester

3.3.2.1 -The umbilical cord

During the second trimester a mass of large pale cells with dark round nuclei appeared near the allantoic duct. These cells were surrounded by many layers of mesenchymal cells and found in the different parts of the centre of the cord (Fig. 21). At a later stage, these pale cells appeared between the constituents of the dermis which covered the umbilical part of the cord near the primitive hair roots (Fig. 22). The cord size and its constituents were increased and the cord consisted of mesenchymal cells and fibroblasts (Fig. 23), and the cord was surrounded with foci of squamous metaplasia on the surface of the amnion. Spherical small cells with elongated nuclei lined the base of the amnion while collagen and elastic fibres were found at the edge of amnion (Fig. 24). The blood vessels in the matrix increased in caliber and ramification and some of them had thick musculature, and the number of the matrix cells also increased (Fig. 25).

There was a prominent increase in the size of the media of the umbilical arteries and veins; it was made up of inner longitudinal and

outer circumferential layers. The allantoic duct had processes which extended from the endothelium into the lumen. The lumen of veins was regular but it was irregular in the arteries. At the umbilicus, the growing skin developed a large strand of elastic fibres which covered the cord and separated it from the skin (Fig. 26).

3.3.2.2- The umbilical arteries

The tunica intima consisted of endothelium only. The thickness of the tunica media was double the size of the adventitia. It consisted of dense short smooth muscle fibres arranged in bundles which were branched and anastomosed and arranged in 30 layers, longitudinally oriented in the inner layer and circular and longitudinal in the outer layers (Fig. 27). The muscle fibres increased in thickness from 10.4µm to 26µm with advancing gestation. Many reticular and elastic fibres formed dense network between the muscle fibres (Fig. 28). Tunica adventitia consisted of collagen, smooth muscle and elastic fibres. Many blood vessels were scattered in the adventitia.

3.3.2.3 -The umbilical veins

The tunica intima consisted of endothelium but lacked internal elastic lamina. Tunica media consisted of smooth muscle fibres arranged in bundles which were branched and anastomosed (Fig. 29), and these bundles were arranged in inner longitudinal and outer circumferential and longitudinal bundles separated by elastic, reticular and collagen fibres. The bundles of muscle fibres increased in thickness from 7.8 µm to 13µm. The adventitia (350 µm) was twice as much as the size of the media (180 µm) and consisted of collagen and elastic fibres and small blood vessels. The lumen of the veins was regular (Fig. 30). At the sinus region of the two umbilical veins during second trimester, the smooth muscle fibers in the tunica intima were

arranged longitudinally and increased toward the external part of the tunica media of the sinus region while decreased in the internal part of the tunica media. In this stage, the smooth muscle fibres were small in size. The adventitia consisted of smooth muscle fibers embedded in loose connective tissue. The nerve fibres were abundant in the adventitia of the two veins (Fig. 31).

3.3.2.4 -The allantoic duct

The lumen was lined with transitional (urothelial) epithelium followed polygonal cells with round nuclei and the number of these cells increased to make stratified layers under the epithelium (Fig. 32)**.** There was a middle layer of connective tissue with blood vessels oriented vertically toward the lumen of the duct. The outer layer consisted of a band of smooth muscle fibres arranged in different directions; oblique, circular and longitudinal. Connective tissue filled the large spaces between the muscle fibres (Fig. 32).

3.3.2.5 -The ductus venosus

The tunica intima consisted of an endothelium of thin simple squamous cells and subendothelial layer of dense elastic and reticular fibres and fibroblasts and fine smooth muscle fibres. The middle layer consisted of mesenchymal cells, fibroblasts, smooth muscle-like fibres elastic and reticular fibres (Fig. 33). The adventitia consisted of fibroblasts and mesenchymal cells embedded in loose connective tissue of elastic fibres. Numerous blood vessels and nerve fibres were found at the terminal ends of the ductus venosus. The size of the intima and the adventitia at the middle part of the ductus venosus was increased due to an increase in the amount of collagen, elastic and reticular fibrse in the two layers.

3.3.2.6 -The ductus arteriosus

The tunica media was thick and consisted of smooth muscle fibres arranged in two layers; inner layer of smooth muscle fibres embedded in reticular and elastic fibres and outer layer of lamellae of smooth muscle fibres with elastic fibres which were concentrated toward the adventitia.

The tunica media and tunica adventitia of the ductus arteriosus merged with the tunica media and tunica adventitia of the aorta cranially and with the media of the pulmonary trunk caudally at their confluence (Fig. 34). The adventitia consisted of connective tissue with small blood vessels and rich in nerve fibres especially in the adventitia at the junction of the ductus arteriosus with the aorta and the pulmonary trunk. The smooth muscle lamellae of the tunica media increased in size and branched and anastomosed gradually with advancing gestation (Fig. 34).

3.3.2.7 -The aortic body

The aortic bodies consisted of acinus-like structures of glomiformed type I, type Π cells and nerve fibres (Figs. 35, 36). The nuclei of type I cells were moderately stained and had one or two nucleoli while type Π cells had darkly stained round nuclei. Each acinus was surrounded with well defined basement membrane and many small capillaries and elastic and collagen fibres were found between the acini (Figs. 37, 38).

Another type of cells, arranged in small and large masses, were scattered in the connective tissue between the aorta and pulmonary artery, approximately at the level of the semilunar valves, and also within the subepicardial connective tissue in the sulcus coronaries (Fig.39). These cells were encapsulated with collagen fibres and many

elastic fibres and characterized by the fact that they were very large rounded pale cells with large pale round nuclei. Small cells with dark nuclei, well supplied with capillaries, and small dark cells in form of islands were found at the periphery of the above mentioned cells (Fig. 40).

3.3.2.8 -The carotid body

More than 9 masses of small carotid bodies with one large central mass were scattered in the connective tissue at the origin of the internal carotid artery (Fig. 41). Cells of carotid bodies were arranged in an acinus-like structure (Fig. 42).

3.3.2.9- The aortic sinus

The intima was thick and consisted of endothelial cells and loose subendothelial layer of elastic and fine smooth muscle fibres (Fig. 43). The media consisted of lamellae of elastic fibres, smooth muscle fibres and small and large masses and nerve fibres (Fig. 43). Many types of cells were found in these masses; mesenchymal cell, small cells with long dark granulated nuclei and fibroblasts. These masses were partially encapsulated and they were rich in elastic fibres.

3.3.2.10- Carotid sinus

The size of the intima and media was equal to those of the common carotid artery, but the size of the adventitia was greater than that of the common carotid artery and contained many nerve bundles (Fig. 44).

3.3.4-Third trimester

3.3.4.1 -The umbilical cord

The size of the cord (25 mm in diameter) and its constituents increased. The wall of the arteries was very thick, and it was folded and at the end of this term the wall collapsed and no lumen was seen. The lumen of veins was very small. The matrix of the cord, like that of the first trimester, consisted of a few small mesenchymal cells and fibroblasts and plenty of collagen and elastic fibres. The cluster of cells which appeared in the second trimester was also seen in the third trimester.

3.3.4.2 -The umbilical arteries

The tunica media of the arteries during this trimester was very thick, and arranged in inner longitudinal layer and outer circumferential layer with some longitudinal bundles of smooth muscle fibres. The thickness of the media varied from 300 μm to 420 μm with an average of 360 μm. Dense connective tissue of collagen, elastic and reticular fibres was also found in the media. The adventitia was equal in size to the media. The wall was completely collapsed leaving only a narrow cleft.

3.3.4.3 -The umbilical veins

The tunica media increased in size and arranged in three layers of smooth muscle fibres; inner and outer circumferential and middle longitudinal layers with a thickness ranging between 270 μm and 340 μm with an average of 305 μm. The adventitia was almost double the size of the media and contained blood vessels and consisted of smooth muscle, collagen and elastic fibres. The sinus wall was thick due to an increase in smooth muscle fibers in the tunica intima, and in the tunica media the fibres were in the form of layers arranged in different

directions and extended to the adventitia. The adventitia consisted of smooth muscle fibres and rich in nerve fibers and blood vessels (Fig. 45).

3.3.4.4 -The allantoic duct

The height of the epithelium retracted (Fig.46). The middle layer increased in size and many spirally arranged blood vessels extended from the middle layer toward the lumen of the duct. The outer layer consisted of circular and many longitudinal smooth muscle fibres together with elastic and collagen fibres and blood vessels (Fig. 46).

3.3.4.5- Ductus venosus

At the terminal end of the duct, the endothelium consisted of simple squamous cells and followed by subendothelial layer of dense elastic and reticular fibres and fibroblasts and fine smooth muscle fibres. The middle layer consisted of mesenchymal cells, fibroblasts and elastic and smooth muscle-like fibres, this layer increased in size and the elastic fibres increased in number and arranged at the peripheral part of this layer forming external elastic lamina. The adventitia became a large layer and it consisted of condensation of elastic fibres arranged in longitudinal orientation and accumulation of smooth muscle fibres and numerous small blood vessels (vasa vasorum) and rich in nerve fibres.

This layer extended into the liver parenchyma. The middle part of the ductus venosus consisted only of two layers, the middle layer of smooth muscle-like cells was absent and so were the nerve fibres in the adventitia in this part of the ductus venosus. Also, the two layers of the middle part of the ductus venosus increased in size due to an increase in the fibre components.

3.3.4- Ductus arteriosus

During third trimester the thickness of the media was increased due to an increase of smooth muscle fibres and elastic fibres. The part of the ductus arteriosus which passed within the aortic wall has rich blood supply in the media. Compared the aorta, the ductus arteriosus has a thicker wall with many smooth muscle fibres and a few elastic fibres in the form of lamellae. The lumen was small and folded (Fig. 47).

3.3.4.7 -The aortic body

Type I cells (chief cells) had large, pale nuclei and moderately stained and finely granulated cytoplasm. Some of these cells were light and some were dark; the light cells had faintly eosinophilic cytoplasm with very large granulated eccentric nuclei while the dark cells had small dark nuclei with clear cytoplasm (Fig. 48). Type Π cells (glomus cells) had the same structure as type I cells but they were small and lacked granules. Type Π cells were less regular with no clear cell boundaries, and they were in contact with the capillaries (Fig. 48).

3.3.4.8 -The carotid body

The cells of the carotid bodies were arranged in the form of acini; type I cells were round and granulated and possessed large heterochromatin nuclei in the majority of cells (Fig. 49). Type Π cells were few and had clear granulated cytoplasm. Fibroconnective tissue capsule covered the carotid body (Fig.50). Network of capillaries and nerve fibres were found inside the carotid bodies (Fig. 50).

3.3.4- The aortic sinus

The aortic wall in the vicinity of the sinus was thick. The tunica intima consisted of endothelium and subendothelia layer of elastic and fine smooth muscle fibres. The media was thick and consisted of lamellae of elastic and smooth muscle fibres and large bundles of encapsulated nerve fibres. The adventitia was rich in elastic, collagen and nerve fibres and small blood vessels were found near the coronary artery.

3.3.4.10- The carotid sinus

Endothelium lined the sinus. Thick internal elastic lamina separated the thin intima from the thick media. The media consisted of numerous lamellae of elastic fibres with a few smooth muscle fibres in between.

3.4 -Histochemistry

3.4.1- PAS-Positive material

3.4.1.1- Carotid sinus

During first trimester the intensity of PAS-positive diastase resistant material was weak (Fig. 51), but during second and third trimesters, the sinus showed a strong PAS-positive diastase resistant material in the tunica intima and media. Glycogen granules were demonstrated in red blood cells.

3.4.1.2- Aortic sinus

During first trimester, the reaction of the PAS-positive diastase resistant material in the aortic sinus was moderate in the entire wall of the sinus (Fig. 52). During second and third trimesters, the aortic sinus showed a strong PAS- positive diastase resistant material in the lining epithelium, elastic fibres of the tunica media and adventitia and in the

nerve fibers within the media. Glycogen granules were demonstrated in the cardiac muscles and red blood cells.

3.4.1.3- Carotid body

The intensity of the PAS diastase digested material was weak during the first trimester. During second and third trimesters, carotid body showed a moderate PAS-positive diastase digested material in the boundaries of the acini, nerve fibres (Fig. 53) and type Π cells. Glycogen granules were demonstrated in red blood cells and in type Π cells (Fig. 54, 55).

3.4.1.4 -Aortic body

During first trimester, the aortic body showed slight PAS-positive diastase digested material in the entire mass of the aortic body. During second and third trimesters, a strong PAS-positive diastase digested material was demonstrated in the aortic body capsule and at the boundaries of the acini-like structures. Moderate reaction was shown in the nerve fibres within the aortic body. Glycogen granules were visible in the cardiac muscles and in the red blood cells (Fig. 56).

3.4.2 -Phosphatases

The cytochemical demonstration of phosphtases under light microscopy depends on the formation of an insoluble coloured precipitate at sites of substrate hydrolysis.

3.4.2.1 -Alkaline phosphatase

3.4.2.1.1- Aortic and carotid sinus

The positive reaction for alkaline phosphatase activity appeared as black staining at the sites of this enzyme. In the carotid and aortic sinuses the sites of positive reaction appeared in both the tunica intima

and the outer part of the tunica adventitia while the tunica media was negative during gestation period (Fig. 57).

3.4.2.1.2 -Aortic and carotid bodies

The reaction was demonstrated in between and around the nerve fibres of the carotid and aortic bodies (Fig. 58). The intensity of staining and number of positive granules in these bodies varied in different parts of the bodies and also with advancing gestation (Fig. 59). The reaction during the three trimesters appeared weak or negative in some specimens (Fig. 60, 61).

3.4.2.2 -Acid phosphatase

3.4.2.2.1 -Aortic and carotid sinuses

The sites of activity were found in both the tunica intima and adventitia of the carotid and aortic sinuses but in the tunica media, the reaction was either negative or weak (Fig. 62). During the first and third trimesters, the activity was stronger in both the media and adventitia of the aortic and carotid sinuses than during the second trimester (Fig. 63).

3.4.2.2.3- Aortic and carotid bodies

The sites of enzyme activity in aortic bodies and carotid bodies were detected by formation of black / brown colours. In the carotid bodies and aortic bodies, the sites of enzyme activity were demonstrated by positive staining reaction at sites of nerve fibres which were found inside these bodies (Fig.64). The intensity of staining and number of positive granules in these bodies varied quite considerably; the granules were either scanty, few or plenty (Fig. 65).

Table 6: Showing dimensions of different structures in the umbilical cord during first trimester.

The organs	Thickness (µm)			Diameter (µm)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Umbilical cord				7000	25000	16000
Umbilical vein 1	131.5	789	460	578.6	789	683.8
Umbilical vein 2	131.5	526	328.5	526	1525.4	1025.7
Umbilical artery 1	330	526	328	1001.9	1262.4	1132.1
Umbilical artery 2	330	627.5	478.5	844.1	1841	1342.5
Allantoic duct	275	550	412.5	1265	2530	1897.5

Table 7: Showing dimensions of different structures in the umbilical cord during second trimester.

The organs	Thickness (µm)			Diameter (µm)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Umbilical cord				14000	27000	20500
Umbilical vein 1	789	1841	1315	2551.1	5786	4168.5
Umbilical vein 2	550	1100	825	1889	3225.7	2557.3
Umbilical artery 1	880	1315	1097.5	2706.8	3497.9	3102.3
Umbilical artery 2	880	1980	1430	2549	5140	3844.5
Allantoic duct	789	1100	944.5	2630	3278.3	2954.1

Table 8: Showing dimensions of different structures in the umbilical cord during third trimester.

The organs	Thickness (µm)			Diameter (µm)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Umbilical cord				20000	30000	25000
Umbilical vein 1	2104	2367	2235.5	5940	6496.1	6218
Umbilical vein 2	1540	2104	1822	4400	5917.5	5158.7
Umbilical artery 1	1430	1980	1705	4175	5801	4988
Umbilical artery 2	2310	3156	2733	6198	9862	8030.2
Allantoic duct	1052	1315	1183.5	3208	7120	5164

CHAPTER FOUR

DISCUSSION

4.1The foetal circulation

In camel foetus, blood from the placenta was carried to the foetus by two large umbilical veins which emptied into a venous sinus and then one vein emerged and entered the liver. The umbilical vein was joined by the portal vein and emptied into the ductus venosus. Blood, in most mammals, passes from the placenta and enters the foetus via one large umbilical vein embedded in the umbilical cord (Kent and Carr, 2001). Some blood enters the ductus venosus and is carried to the caudal vena cava. The remaining part of blood passes through the hepatic sinusoids and is mixed with blood from the portal vein. This blood also enters the vena cava. The remaining part of the foetal circulation of the camel, in this investigation, is similar to that of other mammalian species including ruminants, carnivores, pigs and equines (Kent and Carr, 2001; McGeady ***et al.,*** 2006) and in human (Sadler, 1995).

In the present investigation blood in the aorta is returned to the placenta of camel through two large umbilical arteries which arise from the caudal aorta after giving the external iliac arteries. In other animals, however, blood is returned to the placenta through two large umbilical arteries which are branches of the internal iliac arteries (Getty, 1975).

4.2- Anatomy

4.2.1 -The umbilical cord

The umbilical cord of the dromedary camel in this investigation is long and contains four blood vessels (two arteries and two veins) and a large allantoic duct similar to those of some wild animals like the African lion, Speke's Gazalle and Alpine Ibex (Benirschke and Miller, 1982). Tibary (1997) stated that the umbilical cord contains four blood vessels and a large allantoic duct in the Bactrian camel. The cord contains two arteries and one vein in addition to a widely patent, thin walled allantoic duct in the horse (Whitwell, 1975; Hong ***et al***., 1993). However, McGeady ***et al.*** (2006) reported that the body of the cord consists of two fused umbilical arteries and two fused umbilical veins in the mare and sow. In the present investigation, the umbilical cord is completely covered with the amnion except at the navel which is covered by skin and this finding confirms the findings of Morton (1961), Ghazi ***et al.*** (1994) and Mohammed (2008) in the same species. The umbilical cord of the horse is long and the proximal three-fifths of the cord are surrounded by the amnion and the distal two-fifths by the allantois ((Noden and de Lahunta, 1985).

In horses, dogs and cats, the umbilical cord is divided into an amniotic and allantoic portion due to the arrangement of the foetal membranes in these species (McGeady ***et al.,*** 2006). In cattle, sheep and pigs, the amnion is reflected onto the surface of a short umbilical cord. Mohammed (2008) reported that the amniotic membrane of the dromedary camel covers the allantois and the two membranes fuse together to form the allanto- amniotic membrane at the distal end of the umbilical cord; the amnion forms the zone of attachment to the

chorion and is reflected lateroldorsally and fuses with the chorion to form the chorio-amniotic membrane. In the present study, the amniotic portion of the umbilical cord of the dromedary camel is longer than the allantoic portion and this finding is similar to the finding of Whitwell (1975) in the horse.

At three months of gestation, amniotic plaques develop in the amniotic and the umbilical stalk ectoderm (Noden and de Lahunta, 1985). Wild animals (Speke's Gazalle, Alpine Ibex and Nile Hippopotamus) have numerous plaques of squamous metaplasia on the surface of their umbilical cord. Morton (1961) observed small amniotic pustules, measuring up to 1cm. in diameter and fine bristle-like horns up to 15mm in length in the umbilical cord of the dromedary camel. In this investigation the amnion of the dromedary camel has clusters of white to yellowish projections which develop during the first trimester.

Malas ***et al.*** (2003) reported that there is a positive correlation between gestation age and umbilical vessel measurements. In the dromedary camel in the present investigation there is also a positive correlation between gestation age and the umbilical vessel measurements. There is a considerable variation in the length of the cord ranging from 36 to 84 cm in the thoroughbred foals, and this variation is mainly in the amniotic portion. Excessive lengths of the umbilical cord between 30.5 and 137.2 cm have been considered to be a cause of abortion, foetal strangulation, and foetal demise (Caslick, 1932; Whitwell, 1975).

The length of the umbilical cord varies quite considerably among the species (Eurell and Frappier**,** 2006; Benirschke and Miller,

1982). Similar variation in length occurs in human; and short cords may lead to lack of foetal motion (Benirschke, 1994; Snider, 1997). Adinma (1993) reported that cord length varied in human between 15 cm and 130 cm and the length is not affected by maternal age or sex of baby in human foetuses. Tibary (1997) stated that the length of the umbilical cord reaches up to 110 cm in Bactrian camel while the cord of llama is 30-50 cm long and 2-3cm in diameter (Fowler and Olander, 1990). The most well developed placenta of Bactrian camel has an umbilical cord of 63 cm long, while in the dromedary camel, the length of the cord reached up to 75 cm long. The length of the cord increases in correlation with foetus weight and gestational age, up to time of delivery (Fowler and Olander, 1990).

There is a correlation between umbilical length and weight of the placenta, with a variation according to the position of the foetus. (Adinma, 1993). This correlation is longest in cord encirclement and unstable position and shortest in breech presentation, transverse position, and twin birth (Adinma, 1993). Skulstad ***et al.*** (2005) stated that cord length is positively related to birth weight and weight of the placenta, but an increased length of the cord is also associated with decreasing birth weight / placenta ratio for male foetuses only. Tibary (1997) reported that there are many usually clockwise spirals of the umbilical cord of the camel. The immature lama foetus had a few cord spirals (Fowler and Olander, 1990). Clockwise spirals were observed in the dromedary camel umbilical cord in this investigation.

4.2.2 -The allantoic duct

In the umbilical cord, the allantoic duct is a sac like structure and primarily involved in nutrition and excretion, and is webbed with

blood vessels. It collects liquid waste from the embryo, as well as to exchange gases used by the embryo (Downs, 1998). The allantoic duct in the dromedary camel in the present study is large in caliber at the distal part of the cord and gradually deceases in caliber toward the navel, so that the circumference of the allantoic duct is bigger in the distal part than in the proximal part of the umbilical cord.

4.2.3 -The umbilical vessels

The umbilical vein receives the oxygenated blood from the placenta. Its radicals converge, in the horse, to form a single large trunk in the umbilical cord and passes forward along the abdominal floor in the free border of the falciform ligament of the liver. It then joins the portal vein, so that the blood conveyed by it passes through the capillaries of the liver before entering the caudal vena cava (Sisson, 1953). Two umbilical veins pass through most of the length of the umbilical cord of carnivores and ruminants and they join to form the left umbilical vein before entering the body of the embryo ((Noden and de Lahunta, 1985). There are two umbilical veins in the dromedary camel along the entire length of the umbilical cord in this investigation with differences in the size of the two veins during gestation age. The two veins merged and united after entering the abdominal cavity in a venous sinus. In the ox and dog, some of the blood in the umbilical vein is conveyed directly to the caudal vena cava by the ductus venosus. The vessel is given off within the liver, from a venous sinus formed by the confluence of the portal and umbilical veins, and passes directly to the caudal vena cava (Sisson, 1953). In the horse and pig, the umbilical veins fuse within the amniotic part of the cord, while in other species they fuse on entering

the abdominal cavity (McGeady ***et al.,*** 2006). There were two veins in dromedary camel, in the present study, and this may be due to the type of the placenta of camel which is represented by the endometrium and two bilaminar membrances in the foetal side (chorio-amniotic membrane and chorio-allantoic membrane) as reported by Mohammed (2008). Morton (1961) reported a similar result in three species of camelidae, and also by Fowler and Olander (1990) in the lama glama. The two veins merged and united after entering the abdominal cavity in a sinus in the present study, about 0.5 cm from the liver during first trimester and about 8 cm during the third trimester in dromedary camel. This finding agrees with the finding of Hediger (1962) and Benirschke and Miller (1982) in Hippopotamus, in which the two veins join immediately after entering the abdomen to form a single vein. The Hippopotamus has epitheliochorial placenta with diffuse villi (Teuscher, 1937; Benirschke and Miller, 1982) similar to the camel placenta and this type of placenta may be related to this pattern of umbilical veins and its fusion. However, the two veins in African Lion course in the abdomen, one to the right of the liver hilus while the other to the left of the vena cava (Benirschke and Miller, 1982) although it has endotheliochorial placenta (Benirschke and Miller, 1982; Dantzer, 1999).

The umbilical arteries, right and left, are large vessels which arise from the internal iliac arteries in equine, bovine, dogs and pigs and goat (Getty, 1975). In the dromedary camel, in the present study, the umbilical arteries arise from the abdominal aorta beyond the origin of the external iliac arteries and this finding confirms the finding of Smuts and Hout (1987) in the adult dromedary camel.

The location of the umbilical veins and the umbilical arteries vary along the length of the cord in the present study. The old course of the umbilical vein is represented in the adult by the round ligament of the liver. This ligament starts from the umbilicus and passes through the falciform ligament and the ligamentum venosum within the substance of the liver (Carlson, 1981). In the adult ox, sheep and goat, the falciform and round ligaments are absent (Nickel, 1973; Getty, 1975). All ligaments are present in the horse (Bradley, 1946; Getty, 1975) and man (Snell, 2000). The round ligament is absent in the dog (Sleight and Thomford, 1970) and the pig (Getty, 1975). After birth, the arteries retract with the bladder to the pelvic cavity, their lumen becomes greatly reduced and the wall thickened so that they are cord – like and are usually termed the round ligament of the bladder (Sisson, 1953). The proximal portions of the umbilical arteries are retained in a relatively reduced size as the hypogastric or internal iliac arteries as in human (Sadler, 1995). Similarly, the proximal parts of the umbilical arteries persist as the internal iliac arteries in the dromedary camel in the present investigation. The fibrous cords extending from these arteries, represent remain of the more distal portions of the old umbilical arteries, and are known as the lateral umbilical ligaments in the adult (Carlson, 1981). The segment located between the bladder and the umbilicus in the median ligament of the bladder completely degenerates, but a remnant does persist between the internal iliac artery and the bladder (Noden and de Lahunta, 1985).

4.2.4- The ductus venosus

In pups, the ductus venosus is a straight vessel and arises from the left main portal vein and terminates in an ampulla into which the

left hepatic and phrenic veins drain. The ampulla finally joins the caudal vena cava (Burton and White, 1999). In the dromedary camel, in the present study, the ductus venosus is a straight tubular duct and begins from the union of the left main portal vein with the umbilical vein. The duct passes between the left lateral lobe of liver and the papillary process of the caudate lobe, and joins the posterior vena cava caudal to the left hepatic vein. Kiserud (1999) reported that, the amount of blood shunted in the human foetus seems to be less (25-40%) than in the animal foetus (50%). The diameter of the ductus venosus is 50% of the diameter of the umbilical sinus in human foetuses, and the ductus venosus joins the left dorsal side of the inferior vena cava (Momma ***et al.,*** 1992). The ductus venosus persists until birth in carnivores, ruminants, and primates. However, it disappears during gestation in the pig and horse (Noden and de Lahunta, 1985). After birth, in human, the ductus venosus narrows rapidly and is closed completely in 2 days after birth (Momma ***et al.,*** 1992). After it closes, the remnant of the ductus venosus is known as the ligamentum venosum (Carlson, 1981). It is attached to the left branch of the portal vein, within the porta hepatis, and often may be continuous with the ligamentum teres (Momma, ***et al.,*** 1992). In the present investigation, the ductus venosus in the dromedary camel is devoid of branches and makes an acute angle with the hepatic vein and the posterior vena cava and it is almost at right angle with the portal vein.

4.2.5 -The ductus arteriosus

In the developing foetus, the ductus arteriosus is a shunt connecting the pulmonary artery to the aortic arch and allows most of the blood to be pumped directly from the right ventricle to the aorta

and bypasses the fluid-filled foetal lungs. During foetal development, this shunt protects the lungs from being overworked and allows the right ventricle to be strengthened (Zahaka and Patel, 2002). In the present study, the dromedary camel ductus arteriosus is a muscular shunt connecting the pulmonary trunk to the aortic arch. It is a straight conduit about 1 mm in length during the first trimester and 18 mm in length during the second trimester and 20 mm in length and10 mm in diameter during third trimester. At birth the reduced pulmonary resistance allows more blood to flow from the pulmonary arteries to the lungs and thus the lungs deliver more oxygenated blood to the left heart. This event furtherly increases aortic pressure so that the flow of blood in the ductus arteriosus may transiently be reversed (Zahaka and Patel, 2002). After birth, ductus arteriosus is rapidly transformed into a fibrous cord known as the ligamentum arteriosum (Sisson, 1953). In normal newborns, the ductus arteriosus is substantially closed within 12-24 hours after birth, and is completely sealed after three weeks (Zahaka and Patel, 2002)

4.2.6 -The aortic bodies

The aortic bodies are small microscopic clusters of chemoreceptor tissue. Most of them lie on the surface of the aortic arch and pulmonary trunk, and there are a few on the root of the right subclavian artery (Getty, 1975). The aortic bodies are derived from the neural crest (Krause and Cutt, 1994). These sites are consistent with the principle that baroreceptor and chemoreceptor zones lie on the root of the embryonic arterial arch.

The aorta and right subclavian arteries are derived from the fourth pair of the aortic arches while the pulmonary arteries arise from

the sixth pair (Getty, 1975). In the dromedary camel the aortic body, in the present investigation, is located in the wall of the arch of the aorta, and there are others in the origin of the right subclavian artery and pulmonary trunk. Its arterial supply comes from the aorta itself.

The nerve supply of the aortic bodies consists essentially of chemoreceptor afferent axons. The fibres from the aortic bodies travel through the vagus nerve, but in a few species the aortic bodies have a separate aortic nerve (King, 1999).

The aortic bodies are grossly ill-defined and are not much more than a clump of cells. Consequently their number and location are difficult to establish, and have been carefully studied in a few species (Comroe, 1964). The dog and cat have well developed aortic bodies, but the mouse and rat have poorly developed or no aortic bodies (Comroe, 1964). Nonidez (1937) found about 20 aortic bodies in the dog on the arch of the aorta and pulmonary trunk, and about 15 of these were scattered over the ventrocaudal aspect of these great trunks. Moreover, about half a dozen other aortic bodies lie on the dorsocrainal aspect of these large vessels. One or two more bodies were seen on the root of the right subclavian artery. There seems to be great variation in the number and location of the aortic bodies within the same species (Smith and Hamlin, 1977). The developing sixth aortic arch does indeed supply a pulmonary arterial branch to the aortic bodies on the pulmonary trunk, but only in the foetus or neonate, as in human fetus and neonate kitten (Comroe, 1964). This blood supply is supplemented by branches from the systemic circulation, usually from the left coronary artery. After birth, the pulmonary arterial branch regresses completely in these species. In

young kitten, there is a transitional stage between the pulmonary and systemic arterial supplies, during which the blood supply is switched to the aorta.

This is achieved by an initial proliferation that occludes the pulmonary opening (Comroe, 1964). In the adult dog, the arterial supply of the aortic bodies is achieved by a small branch from the ascending aorta, while in the adult cat and man, it comes from the coronary artery, usually the left (Comroe, 1964). The venous drainage of the aortic bodies is always performed by small veins empting into the cranial vena cava, either directly or via the left costocervical vein (Comroe, 1964).

In a few mammalian species, the aortic nerve is a depressor nerve; it runs from the aortic region as an independent nerve, joins the root of the cranial laryngeal nerve and then continues centrally in the vagus (King, 1957; Bloom and Fawcett, 1962). This occurs in the rabbit, on both sides of the neck. A fully independent aortic nerve also occurs on the left side in the cat and the badger (Meles Meles) and lion (Amoroso, ***et al.,*** 1951). Grau (1943) also reported its occurrence in the pig. It is stated that, in species lacking an independent aortic nerve, the afferent fibers from the aortic bodies are usually incorporated within the recurrent laryngeal nerve. King (1957) and Comroe (1964) referred to this nerve as semi-independent aortic nerve.

4.2.7- The carotid bodies

The carotid bodies are flattened bodies, about 3 mm wide and 5 mm long, associated with the vessel wall at the bifurcation of the common carotid into internal and external carotid arteries. These

bodies are chemoreceptors sensitive to high carbon dioxide concentration, low oxygen tension and low arterial blood pH (Junqueria and Carneiro, 2005).

Dromedary camel carotid bodies in the present investigation are masses of cellular connective tissue at the point of origin of the internal carotid artery from the common carotid artery. The distribution of the carotid bodies at the bifurcation of the common carotid artery and the internal carotid appear in the first trimester as small series of carotid bodies which increase in size with gestation.

4.2.8- The Aortic sinuses

The aortic sinuses are specialized receptors responsive to alteration in blood pressure and they are innervated by the vagus nerve (Banks, 1993). King (1999) reported that the aortic sinus is one of the anatomic dilations of the aorta which occurs just above the aortic valve. In the present study, dromedary camel aortic sinus is located in the wall of aorta, above the cusps of the aortic valve at the origin of the coronary arteries.

The afferent axons belonging to this sinus come from a bundle of axons known as the aortic nerve. In most mammals, this bundle or axons is buried in and supplies the arch of the aorta, and comes from the right vagus to supply the root of the right subclavian artery. In a few species, these fibres form a fully independent aortic nerve (King, 1999).

4.2.9- The carotid sinus

Carotid sinuses are slight dilatations of the internal carotid arteries, and contain baroreceptors that detect changes in blood pressure and relay the information to the central nervous system

(Junqueira and Carneiro, 2005). The mammalian carotid sinus is the baroreceptor area of the common carotid bifurcation commonly situated at the origin of the internal carotid artery or occipital artery (Adams, 1958)

The ninth cranial or glossopharyngeal nerve leaves the skull through the jugular foramen in the dromedary camel. Proximally, it receives a branch from the pharyngeal branch of the vagus nerve and then divides into four branches including the carotid sinus branch, to the carotid sinus (Smuts and Hout, 1987). In the present investigation during the third trimester, it is clear that the common carotid artery of the dromedary camel terminates by giving off a patent internal carotid artery and continues as the external carotid artery. The carotid sinus is present at the origin of the internal carotid artery. The sinus forms a distinct dilatation with thinner wall than the adjoining arterial wall.

4.3 -Histology

4.3.1 -The umbilical cord

The matrix of the cord of camel in the present investigation consists of gelatinous substance which contained mesenchymal cells, large fibroblasts, muscles and collagen fibres and numerous small blood vessels. In equines, the umbilical cord contains numerous small blood vessels especially in the vicinity of the allantoic duct. The allantoic portion of the umbilical cord is not a solid cord but in the form of a web of blood vessels (Whitwell, 1975). Numerous small blood vessels are found throughout the cord substance of Bactrian camel, some with thick musculature (Fowler and Olander, 1990). The mouse allantois consists of mesodermal tissue which undergoes vasculogenesis to form the mature umbilical arteries and veins

(Downs, 1998). Remnants of the vitelline duct may be present in equine umbilical cord (Whitwell, 1975). In the present investigation, the two arteries were unequal in size while the two veins were almost equal in size.

The cord in the equine may be significantly spiraled and, in the amnionic portion, it has many small foci of squamous metaplasia on its surface (Whitwell, 1975). The umbilical cord of Bactrian camel is covered with dark skin-like squamous tissue (Fowler and Olander, 1990).

Bactrian camel has transitional (urothelial) epithelium lining the allantoic duct and in sites, it becomes squamous in nature (Fowler and Olander, 1990).

In ruminants and in the horse, the umbilical cord and umbilicus are ensheathed with smooth muscle which contracts in response to stretching of the cord at parturition (Noden and de Lahunta, 1985). Hamilton and Dow (1962) stated that the horse and rabbit have sphincters in the region of the umbilical ring.

The umbilical cord cross-sectional area and the amount of Wharton's jelly increases with gestation from 20 to 31-32 weeks of foetal age and remains at the same level for the rest of pregnancy (Skulstad, ***et al.,*** 2006). At mid gestation, about 70% of the cord cross-sectional area is occupied by Wharton's jelly while at 31 weeks and later this value was reduced to 60% (Skulstad ***et al***., 2006). In dromedary camel in the present study, the amount of the Wharton's jelly occupies about 70% of the cross-section of the umbilical cord during the whole gestation age. Matrix cells from Wharton's jelly have recently been identified as a potential source of stem cells (Hill,

2008). It has been discovered that the blood within the umbilical cord, known as cord blood, is a rich and readily available source of primitive undifferentiated stem cells (Simmons ***et al.,*** 1992). Lim ***et al***. (2007) found that transplantation of the umbilical cord blood (UCB)-derived mesenchymal stem cells (MSCs) resulted in recovery of nerve function in dogs with a spinal cord injury and may be considered as a therapeutic modality for spinal cord injury.

In the camel, the umbilical cord consists of four blood vessels and a large allantoic duct; two arteries and two veins. Elastic fibres were found in these blood vessels (Ghazi, 1994).

4.3.2- The Umbilical Arteries

The intima of the dromedary camel, in the present investigation, consists only of endothelium and the internal elastic lamina is interrupted and thin and it is similar to that of other animals and human (Fawcett, 1986). Fragments of elastic laminae developed in the intima and media and both are thicker in arteries than in the vein (Stehbens ***et al.,*** 2005). The tunica media consisted of long smooth muscle fibres arranged in bundles which were branched and anastomed and arranged in about 20 layers at the first 12 weeks of gestation in the present study. The number of layers increased to 55 layers at the end of the first trimester. The external elastic lamina is absent. No external elastic laminae or distinct adventitia are found (Stehbens *et* ***al.,*** 2005). The adventitia was composed of collagen, elastic and smooth muscle fibres and it is almost equal in size to the media. The difference in the size of the two arteries is obvious at the end of this term and the arteries develop faster than the veins in the present study.

There are predictable differences between the vessel and luminal diameters, and the thickness of the tunica media and tunica adventitia of the umbilical vein and umbilical arteries (Malas ***et al.,*** 2003). Hamilton and Dow (1962) reported that all arteries and veins of the umbilical cord have thick muscular walls and lack a nerve supply. The extra-abdominal portion of the umbilical artery is provided with numerous oval swellings and in these regions the wall becomes thin and consists almost exclusively of circularly arranged smooth muscle fibres (Fawcett, 1986). The umbilical arteries, because of their thick muscular tunic and the ability of the lumen to dilate due to the absence of an internal elastic membrane, can function not only as tubes for conducting blood but also as organs that regulate the blood flow (Minh, ***et al.,*** 1985).

4.3.3 -The Umbilical Veins

The result of the present study showed that the umbilical veins have thicker walls than other veins in the adult. It is suggested that they may play a role as a secondary pump according to their thick muscular wall and branching pattern of their smooth muscle just like the heart. This is in agreement with the finding of Minh, ***et al*** (1985) in which of was stated that the umbilical veins can neither stretch nor retract but behave as an organ to return the blood flow due to the presence of an inner limiting layer which prevents over-stretching.

Umbilical vein constriction is associated with reduced umbilical cord cross-sectional area and Wharton's jelly in female foetuses, but not in male foetuses (Skulstad ***et al.,*** 2006).

Under physiological condition, umbilical ring constriction affects umbilical vein hemodynamics, with corresponding effects on

the umbilical cord cross-sectional area and amount of Wharton's jelly. Interestingly, the effects are gender-specific (Skulstad ***et al.,*** 2006).

The veins contain no valves (Sisson, 1953). However valves are observed in branches of the umbilical veins in the dromedary camel in the present investigation. In the present study, the sinus region of the two umbilical veins have well developed and distinct nerve fibres at the adventitia of the sinus; this confirms the finding of Lachenmayer (1971) in which it was shown that the intrafoetal portion of the umbilical vein receives adrenergic nerves in the guinea-pig.

During first trimester, the sinus region of the two umbilical veins, in the present investigation, has a thin muscular wall near the liver. With advancing gestation, the thickness of the wall is increased due to the proliferations of the smooth muscle fibers. The distance between the sinus and the liver also increases till it is embedded within the muscular wall of the abdominal cavity. The investigator failed to find any similar information in the literature.

4.3.4 -The Allantoic Duct

It consists, in the dromedary camel, of three layers and is lined by transitional epithelium as reported by Fowler and Olander (1990) in the bactrian camel and llama. The middle layer consisted of connective tissue with mesenchymal cells and a few fibroblasts. The outer layer contained fibroblasts and mesenchymal cells and smooth muscle fibres.

4.3.5 -The ductus venosus

In the present study, the ductus venosus is divided into middle part and two terminals ends (the umbilico-portal junction and the ductus venosus-vena cava junction). The two terminal ends have a

middle layer of smooth muscle-like fibres and rich in elastic fibres and the external layer consisting of elastic and smooth muscle fibres. The present result is in agreement with the result reported by Ailamazyan ***et al***. (2003) and which showed that the ductus venosus in human foetuses contains elastic, collagen and argyrophilc fibres. The ductal isthmus is an accumulation of smooth muscle cells as an intimal pillow which protrudes into the vascular lumen. The ductal thickness is consistently bigger in the inlet than in the outlet. The tunica adventitia is greatest in the junction with the portal sinus and inferior vena cava than in the intrahepatic parenchyma.

The wall thickness of the portal sinus and the umbilical vein is significantly higher than that of the ductal wall. Mavrides ***et al.*** (2002) reported that, the inlet of the ductus venosus contained a shelf which was rich in elastin, but devoid of any evidence of smooth muscle sphincter in human foetuses. The smooth muscle fibres of the ductus venosus in the present study may regulate the umbilical venous pressure due to an increased resistance to flow in the foetal liver through which some of the umbilical blood passes during development. Membrane-like edge is present at the inner junction of the ductus venosus with the inferior vena cava in neonatal rat (Momma, ***et al.,*** 1992). In the guinea-pig, the ductus venosus is an intrahepatic branch of the vena umbilicalis. No adrenergically innervated sphincter has been detected in the initial segment of the ductus venosus (Lachenmayer, 1971). The structure of the tissue ridge at the junction of foetal sheep ductus venosus was described by Adeagbo, Kelsey and Coceani (2004). This structure is a true sphincter with autonomous regulation of its muscle and the vessel wall is endowed with a noradrenergic innervation. Moreover, Coceani***, et al***

(1984) demonstrated in lamb, a concentration of circularly oriented muscle fibres at the junction of the ductus venosus with the portal sinus (the sphincter region) and adrenergic and cholinergic fibres were visualized in both the sphincter and extrasphincter regions of the ductus venosus. The diameter of the ductus venosus is significantly narrower in pups born alive than stillborn individuals. The ductus venosus has no sphincter and its closure appears to be uniform along the vessel's length in neonatal dog (Burton and White, 1999).

4.3.6 -The ductus arteriosus

In the present study, the ductus arteriosus is a muscular vessel consisting of three layers; intima, thick media and adventitia. The reduced pulmonary resistance allows more blood to flow from the pulmonary arteries to the lungs and thus the lungs deliver more oxygenated blood to the left heart. This event further increases aortic pressure so that the flow of blood in the ductus arteriosus may be transiently reversed (Zahaka and Patel, 2002). The adventitia is rich in nerve fibres especially at the junction of the ductus arteriosus with the aorta and the pulmonary trunk. The presence of these nerve fibres may regulate the blood flow within the duct. The increase in the size of the ductus arteriosus due to proliferation of the smooth muscle fibres toward the lumen. The smooth muscle lamellae of the tunica media increase in size and become branched and anastomosed gradually with gestation age. This may indicate the rapid sequence and short duration of occlusion of the ductus arteriosus and the umbilical arteries after birth. This finding is in agreement with Sisson (1953) who reported that after birth ductus arteriosus is rapidly transformed into a fibrous cord known as the (ligamentum arteriosum). In normal newborns, the

ductus arteriosus is substantially closed within 12-24 hours after birth, and is completely sealed after three weeks (Zahaka and Patel, 2002)

4.3.7 -The carotid sinus

The baroreceptors of the right common carotid in the cat are characteristic structures confined to pressure –sensitive region of the adventitia (Boss and Green, 1954).

Traditionally, the carotid sinus has been identified as the dilated portion of the common carotid bifurcation, although in some animals dilation may be lacking (Adams, 1958). Furthermore, sensory nerve fibers are distributed in large numbers only to the carotid dilatation itself and in other confluent vascular areas of the carotid bifurcation region of some species (Rees, 1968). In all cases, the densely innervated arterial wall corresponds to the parts of the carotid bifurcation which have a high density of elastic tissue in the tunica media (Bagshaw and Fisher, 1971; Knoche, ***et al.,*** 1980).The arterial tunica media of the sinus is thinner to allow it to respond to changes in blood pressure. The intima and the adventitia are very rich in nerve endings (Junqueira and Carneiro, 2005).

Fawcett (1986) stated that the tunica media of the carotid sinus is thinner than elsewhere, while the adventitia is thicker and contains a large number of sensory nerve endings derived from the glossopharyngeal nerve; these nerve endings are stimulated by stretching. A presumptive carotid sinus is present at the origin of the internal carotid in the dromedary camel and it is characterized by a comparatively thin vascular wall rich in elastic fibers (Abdel-Magied and Drommer, 1989).

In dromedary camel foetus, in this investigation, the lining epithelium is simple squamous and there is thick internal elastic lamina. The tunica media consisted of about 5 lamellae of elastic and smooth muscle fibres. The adventitia consists of connective tissue rich in cells specially fibroblasts and numerous masses of primitive nerve bundle are found. The author did find any information pertaining to the camel foetus in the literature.

4.3.8 -The aortic sinus

The aortic sinus is an elastic dilation and therefore has a highly elastic wall (King, 1999). The vagus nerve innervates the aortic sinus (Banks, 1993; Gartner and Hiatt, 1997; King, 1999). Omer (2003) stated that the tunica intima of the aortic sinus in dromedary camel is greatly thickened and consisted of collagen fibres and fine elastic fibres. The tunica media is very thin and consists of elastic tissue in the form of fenestrated membranes, while the adventitia is rich in elastic fibres in the form of lamellae. In dromedary camel foetus in this study, the aortic wall in this area is thick. The intima is thick and extends to the inner media. The tunica media consists of elastic fibres arranged in lamellae between the smooth muscle fibres

4.3.9- The carotid body

The carotid bodies are enclosed by a connective tissue capsule and consist of a dense sinusoidal capillary network surrounding clusters of two types of cells (Gonzalez, ***et al.,*** 1994; Eurell and Frappier**,** 2006). The sustentacular cells incompletely invest several granular endocrine cells. Nonmylinated afferent and efferent nerve terminals synapse on granular endocrine cells (Eurell and Frappier **,** 2006).

The carotid bodies are richly innervated by the carotid sinus branch of the glossopharyngeal nerve and by a plexus of sympathetic components from the vagus and glossopharyngeal nerves (Fawcett, 1986). The carotid bodies are highly vascular structures with a large blood flow in relation to their small volume of parenchyma and they consist of irregular clumps of pale- staining epithelioid cells (Fawcett, 1986). These epithelioid cells (glomus cells) have large, pale nuclei and light, finely granular cytoplasm (Krause and Cutt, 1994).

The principal mass of the carotid body of the dog is made up of type 1cells and the immediately adjacent connective tissue (Clarke and Dally, 1982). Caudally and separate from the principal mass, isolated group of periadventitial type 1 cells lie freely in the connective tissue adjacent to the internal and external carotid arteries (Clark and Dally, 1982). The carotid body of the mink is a highly vascular body enveloped by a thin fibrous capsule and sometimes is divided into lobules. It has compact structure with a general sparse stroma much like the carotid body of the cat (Haldow, 1986). In the domestic fowl, the carotid body consists of a dense capsule and parenchyma; the parenchymal elements are type I cells, type Π cells, axonal endings, blood vessels, unidentified cells, collagen and non cellular elements (Abdel-Magied and Drommer, 1989). Some cell nests give a positive chromaffin reaction (Bloom and Fawcett, 1962; Haldow, 1986). At the periphery of each cell nests are a few sustentacular or type 2 cells (Haldow, 1986; Banks, 1993; Dellmann and Eurell, 1998; King, 1999). A few mast cells often occur in the stroma of the body and sometimes also in the surrounding connective tissue. Haldow (1986) found that the carotid bifurcation has small

isolated clusters of chief cells in the adventitia of the regional arteries in the mink. This is also true in the rabbit (Clarke and Dally, 1981), dog (Clarke and Dally, 1982) and cat (Clarke and Dally, 1983).

The carotid body of the camel consists of lobules and each lobule consists of several secondary lobules, the latter in turn consists of acinus –like structures or glomi formed by type I and type Π cells (Etemadi, 1975).

In dromedary camel foetus, in this study, clusters of well stained cells appear at the bifurcation of the common carotid artery and internal carotid artery and surrounded with connective tissue.

Type I and type Π cells of carotid bodies begin to arrange themselves in acinus- like structures during second trimester. During third trimester, the carotid bodies cells are well developed in an acinus-like structure. Hussein, ***et al*** (1998) confirmed this observation and added that the basement membrane of each acinus is in close contact with the cell membrane of both cell types. The carotid bodies are sensitive to changes in pH and temperature (Gonzalez ***et al***., 1994).

4.3.10- The aortic body

The structure of the aortic bodies is identical to that of the carotid bodies (Nonidez, 1937). They are chemoreceptors which monitor gaseous tension, while the Paraaortic bodies are the chromaffin cells which secrete catecholamine (Fawcett, 1986).They are scattered in small islands in the connective tissue between the aorta and pulmonary artery, approximately at the level of the semilunar valves, and also within the subepicardial connective tissue in the sulcus coronaries, mainly along the left coronary artery. The

cells of the Paraaortic bodies are in close proximity to nerve networks and ganglion cells, and they are more highly developed in the newborn than in the adult (Fawcett, 1986). Taha and King (1986) found that there are aggregations of large pale- staining cells in the wall of the aorta and the pulmonary trunk and arteries. These aortic-pulmonary bodies resemble those of the carotid body and have a chemoreceptor function similar to that of the carotid body. Clarke and Daly (2002) reported the presence of paraganglionic tissue in the aorticpulmonary regions of the Marmoset, but has no characteristic histological features of the aortic body chemoreceptors that have been described in some non-primate mammals

In dromedary camel foetus, in the present study, there are cells arranged in small and large masses scattered in loose connective tissue between the aorta and pulmonary artery, approximately at the level of the semilunar valves, and also within the connective tissue in the sulcus coronarius. These cells are encapsulated with collagen fibres and many elastic fibres. It is suggested that these cells are paraortic bodies. The size and distribution of the paraaortic bodies in the dromedary camel foetus are highly developed. No similar findings in the camel foetus are found in the literature.

The aortic bodies are innervated by fibres from the vagus nerve (Banks, 1993; Gartner and Hiatt, 1997). Aortic bodies measure changes in blood pressure and the composition of arterial blood flowing via them, including the partial pressure of oxygen and carbon dioxide but not pH. The chemoreceptors responsible for sensing changes in blood gases are called glomus cells. The glomus cells help the body to regulate breathing when there is a decrease in the blood

pH, a decrease in oxygen (PO2), or an increase in carbon dioxide (PCO2) (Gonzalez ***et al***., 1994).

The histology of the aortic bodies of ruminants, dog and cat is similar to that of the carotid body. It is characterized by the presence of granular cells, sustentacular cells, afferent axonal ending and abundant capillaries and sinusoids (King, 1999). Snell (2000) reported similar findings in the aortic bodies of man. In dromedary camel, the chief cells (light and dark) of the aortic bodies are usually polygonal or round in shape and the eccentric nuclei are spherical, with a very obvious nuclear membrane (Omer, 2003).

There is a cluster of cells surrounded with connective tissue and collagen fibres in dromedary camel foetus, in the present study, during first trimester. The acinus-like structure is not defined. During second trimester the acinus-like structures appear in aortic bodies. During third trimester the aortic bodies consist of acinus-like structures with type I and type Π cells. The nerve supply comes from the vagus nerve.

4.4- Histochemistry

4.4.1- PAS-Positive material:

4.4.1.1- Aortic and carotid sinuses

The PAS reaction is a useful indicator for the presence of tissue carbohydrate, and particularly so for glycogen when the technique incorporates a diastase digestion stage (Bancroft and Stevens, 1990).

The presence of glycogen in foetal tissue was first reported by Bernard (1859). He described its distribution and concluded that it had an important role in organ development. Needham (1931) reported that glycogen was not present to a greater extent in foetal tissue than

in adult tissues. (Shelly, 1961) has shown that during foetal development certain organs accumulate glycogen at particular stage of histogenesis; cardiac glycogen, for example, varies inversely with tissue maturity, while muscle glycogen increases with maturity

While the distribution of epithelial glycogen in human foetuses was investigated by Lev and Weisberg (1969), there has been no comprehensive study of PAS reactions throughout the sensory organs of the arteries in animal foetuses including the camel. Carbohydrate is the sole source of energy in the developing foetus as Needham (1931) and Smith (1959) reported. Bernard (1879) suggested that the placenta is the main storehouse for glycogen utilized by the foetus and the hepatic glycogen appearing only late in foetal life. In the present investigation, PAS- positive diastase resistant material in the aortic and carotid sinuses was low during first trimester. Lev and Weisberg (1969) found small amount of glycogen in the epidermal and oral epithelium of the human foetuses and none was detected in the liver or pancreas in the first trimester. During second and third trimester, camel foetus aortic and carotid sinuses showed strong PAS-positive distaste resistant material in the lining epithelium and this finding is in agreement with the finding of Lev and Weisberg (1969) as noted above. A strong PAS-positive diastase resistant material was demonstrated in the elastic fibres of the tunica media and adventitia of the aortic and carotid sinuses and in the nerve fibers of the tunica media. This finding is in agreement with the finding of Osman (1975) demonstrating the presence of PAS-reactive substances resistant to diastase digestion in the wall of blood vessels of the testis of adult dromedary camel. However the reaction of the carotid sinus during the same periods was moderate. Omer (2003) stated that red blood cells,

basophils and eosinophils were negative to PAS-positive digested material but positive in neutrophils, lymphocyte, platelets and monocyte and this finding is in accord with the present study in which it was shown that the glycogen granules demonstrated in the blood cells of the camel foetus.

4.4.1.2 Aortic and carotid bodies

In the present investigation, during second and third trimesters, a strong PAS- positive diastase digested material (glycogen) was demonstrated in the capsules of the aortic and carotid bodies and in the boundaries of the lobules. Moderate reaction was shown in the nerve fibres and type Π cells of the carotid body. Type I cell was negative. This is probably due to the fact-that the two types of cells contain different substances. According to Becker, Drukker and Meijer (1967) type I glomus cells contain acetylcholinesterase, monoamine oxidase and norepinephrine while type II glomus cells are highly positive for cholinesterase, carbonic anhydrase and nucleoside phosphatases but they do not contain acetylcholinesterase nor catecholamines.

4.4.2- Alkaline phosphatase

4.4.2.1- Aortic and carotid sinuses

As the name suggests, alkaline phosphatases are most effective in an alkaline environment (Harada, Udagawa, Fukazawa, Hiraoka, Mogi, 1986). In humans, alkaline phosphatase is present in all tissues throughout the entire body, but is particularly concentrated in liver, bile duct, kidney, bone, and the placenta.

According to Moog and Wenger (1952), alkaline phosphatase occurs where diastase fast- positive material is found. This correlation is found to be true in the brush borders of the proximal tubules of the

camel kidney (Abdalla, 1973) as well as in both tunica intima and tunica adventitia of the carotid and aortic sinuses in the present observations.

Sawaragi, and Wynn (1969) believed that alkaline phosphatase helped in absorption of glucose. Wislocki and Dempsey (1945) indicated that alkaline phosphatase should be demonstrated in a region supervening between the source of sugar and location where glycogen deposition is occurring.

4.4.2.2- Aortic and carotid bodies

The sites of demonstration of alkaline phosphatase in aortic and carotid bodies of the camel foetus investigated in the present study suggest a similar function as suggested by Wislocki and Dempsey (1945) i.e. a role in the transportation between blood vessels of the aortic and carotid bodies and the cellular elements of these bodies.

The reaction was demonstrated in between and around the nerve fibres of the carotid and aortic bodies. The intensity of staining and number of positive granules in each of these bodies, varied in the different parts of the bodies during gestation. The author did not find any similar information in camel foetus.

4.4.3- Acid phosphatase

8.4.3.1- Aortic and carotid bodies

Acid and alkaline phosphatases are a group of isoenzymes capable of liberating phosphate from many mono phosphate esters. The cytochemical demonstration of phosphatases under light microscopy depends on the formation of an insoluble coloured precipitate at sites of substrate hydrolysis. The activity of acid phosphatase was demonstrated by Wolf, Kabat and Newman (1943) in the nuclei of cells of all tissues. It was suggested that the enzyme may

play a role in nuclear metabolism. In carotid bodies and aortic bodies, the sites of enzyme activity were demonstrated by positive staining reaction at sites of nerve fibres within the structure of these bodies.

This finding confirms that of Wolf, Kabat and Newman (1943) who have shown that the axons contain considerable amounts of acid phosphatase and it is often demonstrated in the individual neurofibrils, while myelin sheath is free of it. This may be due to the relationship of acid phosphatase to the transmission of nerve impulses.

The intensity of staining in each of these bodies, vary quite considerably; the granules may appear scanty, few or plenty and this finding confirms the finding of Omer (2003) on the activity of enzyme in the carotid and aortic bodies of adult dromedary camel.

4.4.3.2- Aortic and carotid sinuses

The sites of activity appeared in both tunica intima and adventitia of the carotid and aortic sinuses but in tunica media, the reaction was either negative or weak in the present investigation. During first and third trimester the activity appeared strong in both media and adventitia of aortic and carotid sinus than during second trimester. This enzyme has not been studied before in the camel foetus. The investigator did not find any information pertaining to the histochemistry of the sensory organs of arteries of the camel or any other mammal.

Conclusions

1- The dromedary camel foetal circulation is similar to other domestic mammals, but it differs in some aspects.

2- The blood enters the foetus through two large umbilical veins which unite in a large intra abdominal venous sinus about 1-8 cm from the liver and drained by one vein to the liver, and this finding is similar to that of some wild animals (Lion and Hippoptamus).

3- The sinus region of the two umbilical veins is muscular in nature.

4- The umbilical region of the umbilical cord has a strand of elastic fibres which separate the skin from the cord at the umbilicus.

5- The umbilical veins and arteries and the ductus arteriosus are muscular in nature.

6- The ductus venosus contained smooth muscle fibres at the junction with the posterior vena cava and with the portal vein.

7- The morphology of the carotid and aortic bodies similar to that of the adult camel but lack the acinus-like structures at the early stages of development.

8- The paraaortic bodies are well developed in camel foetuses.

9- The acid phosphatase enzyme reaction is strong in the carotid and aortic sinuses during first and third trimester, more than in the second one.

10- The alkaline and acid phosphatase enzymes reaction varied quite considerably in carotid and aortic bodies during gestation.

11- Positive alkaline phosphatase reaction was demonstrated in both tunica intima and adventitia of the carotid and aortic sinuses during gestation.

12- Ultrastrctural investigation is needed to elucidate more information for the foetal circulation of dromedary camel and the development of the sensory organs of arteries.

SUMMARY

The present study provided basic information about the foetal circulation and the sensory organs of arteries in the dromedary camel foetus.

1- A total of 60 foetuses were collected from El-Bogaa, El-Salam and Tambool slaughter houses and covered the first, second and third trimesters.
2- Morphological and histological studies of the dromedary camel foetal circulation and sensory organs of the arteries were carried out throughout the three stages of pregnancy.
3- The umbilical cord had two veins and two arteries and a large allantoic duct.
4- The umbilical veins and arteries are muscular vessels with branched and anastomosed smooth muscle fibres.
5- The two umbilical veins united in a large venous sinus near the liver and were embedded within the abdominal wall at the third trimester.
6- The sinus region of the two umbilical veins was large and muscular with an increase in smooth muscle fibres with advancing gestation.
7- The umbilical region of the umbilical cord had a strand of elastic fibres separating the cord from the skin.
8- The ductus venosus had an accumulation of smooth muscle fibres in the tunica adventitia at the two ends of the duct.
9- The ductus arteriosus is a muscular canal joining the pulmonary trunk with the aorta and had branched and anastomosed smooth muscle fibres.

10- There was an increase in the size of the ductus arteriosus due to proliferation of the smooth muscle fibres toward the lumen.

11- The aortic bodies were present at the aortic arch within and outside the wall of the aorta and between the aorta and subclavian artery.

12- The carotid bodies were embedded in connective tissue at the bifurcation of the common carotid into internal and external carotid arteries.

13- The carotid and aortic bodies consist of two types of cells; type I granular cells and type II cells with a few or no granules.

14- The morphology of the carotid and aortic bodies were similar to those of adult camel but lacked acinus-like structures at the early stages of development.

15- The paraaortic bodies were present in groups along the sulcus coronaries near the aortic valves.

16- The aortic sinus was present in the wall of the aorta above the aortic valves. The sinus has a thick wall and the tunica media was intermingled with the tunica intima and contain masses of nerve fibres.

17- A strong PAS-positive diastase resistant material was demonstrated in the lining epithelium, elastic fibres of the tunica media and adventitia and the nerve fibres of the carotid and aortic sinuses during second and third trimesters. A slight PAS-positive diastase resistant material was found during first trimester.

18- A strong PAS-positive diastase digested material was demonstrated in the capsules of the aortic and carotid bodies and in the boundaries of the lobules of these bodies. Moderate reaction was shown in the nerve fibres of the carotid and aortic bodies.

19- A strong acid phosphatase reaction was demonstrated in the tunica intima and adventitia of the carotid and aortic sinuses during first and third trimesters more than during second trimester.

20- The reaction of acid and alkaline phosphatases in carotid and aortic bodies varied quite considerably in different parts of the bodies and also with advancing gestation.

ملخص الأطروحة

هذه الدراسة أعطت معلومات أساسيه عن الدورة الجنينية و الأعضاء الحسيه بشـرايين جنين الإبل .

1- تم جمع 60 عينه من أجنه الإبل من سلخانات البقعه، السلام و تمبول. تم جمـع 10 عينات في الثلث الأول من الحمل ، 25 عينه في الثلث الثاني و 25 عينه في الثلث الثالث من الحمل .

2- تمت الدراسة التشريحية و النسجية للأوعية الدموية في الدورة الجنينية في الإبل و الأعضاء الحسيه بالشرايين خلال فترة الحمل .

3- يحتوى الحبل السري علي وريدين وشريانين بالإضافة لقناه سقائيه .

4- الأوردة والشرايين السرية أوعيه عضلية تحتوي علي عضلات ملساء متفرقـة و متشابكة .

5- يلتحم الوريدان السريان في جيب وريدي واسع بالقرب من الكبـد يلتصـق مـع عضلات جدار البطن خلال الثلث الأخير من الحمل .

6- منطقه الجيب الوريدي متسعة و عضلية التركيب و تتزايد فيها العضلات الملساء مع تقدم نمو الجنين .

7- منطقه الحبل السري بالقرب من السره تحتوي علي حزمه عريضة من الألياف المرنة والتي تفصل الحبل السري عن الجلد .

8- تحتوى القناة الوريدية علي ألياف عضلية ملساء في الطبقة الخارجية خاصة عنـد نهايتي القناة.

9- القناة الشريانية قناة عضلية تربط الجذع الرئوي مـع الأبهـر و تحتـوي علـي عضلات متفرعة و متفاغره .

10- الزيادة في حجم القناة الشريانية في مراحل النمو المختلفة ناتج مـن تزايـد نمـو العضلات الملساء تجاه تجويف القناة.

11- الأجسام الأبهريه توجد في القوس الأبهرى داخل و خارج جدار الأبهـر و بـين الأبهر و الشريان تحت الترقوي .

12- الجيب السباتي يوجد في داخل نسيج ضام في منطقه تفرع الشريان السباتي العام إلى الشريان السباتى الداخلي و الخارجي.

13- الأجسام السباتيه و الأبهريه تتكون من نوعين من الخلايا ، خلايـا النـوع الأول محببة و خلايا النوع الثاني ربما تحتوي علي القليل من الحبيبات .

14- تركيبة الأجسام السباتيه و الأبهريه مشابهه لتلك الموجودة في الإبل البالغة غيـر أنها تفتقر للتركيب المشابه للحويصلات في الفترة المبكرة من عمر الجنين .

15- توجد الأجسام جنيب الأبهريه في مجموعات علي طول الأخدود التـاجي قـرب الصمام الأبهري .

16- توجد الجيوب الأبهريه داخل جدار الأبهر فوق الصمام الأبهـري ، و هـى ذات جدار سميك تتداخل فيه الطبقة الداخلية مع الطبقة الوسطي وتوجـد حـزم مـن الألياف العصبية .

17- تتميز الطلائية المبطنة للجيب الأبهري والجيب السباتي و كذلك الألياف المرنـة في الطبقة الوسطي و الخارجية و حزم الألياف العصبية في الجيب الأبهـري و السباتي بوجود مواد مقاومه للهضم بواسطة إنزيمات اللعاب و التي تتميز بالتفاعل الموجب القوي مع محلول شيف وذلك خلال الثلثين الثاني و الثالث من الحمـل بينما تكون قوه التفاعل أقل في الفترة الأولي من الحمل .

18- تتميز المحفظة و الحواف المحيطة بالفصيصات في الجسم الأبهـرى و السـباتي بوجود مواد قابله للهضم بواسطة إنزيمات اللعاب بينما يكون وجود هـذه المـواد أقل في الألياف العصبية المصاحبة لهذه الأجسام خلال فتر الحمل .

19- لوحظ وجود تفاعل قوى لإنزيم الفوسفاتيز الحمضي في كل من الطبقة الداخلية و الخارجية للجيب الأبهري و السباتي خلال الفترة الأولي و الأخيرة مـن الحمـل بينما لم يظهر تفاعل خلال الثلث الثاني من الحمل .

20- لوحظ تفاعل مختلف القوة لإنزيم الفوسفاتيز القلوي و الحمضي فـي الأجـزاء المختلفة للأجسام السباتيه و الأبهريه خلال فتره الحمل .

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LEGANT OF FIGURES

Fig. 1: Photograph of a foetus during first trimester (109 days), showing allantoic sac (A) covered with amnion and filled with dark allantoic fluid. U: the umbilical cord.

Fig. 2: Photograph of a cast of foetal blood vessels during second trimester, showing umbilical veins (V), umbilical arteries (R), sinus region (S), ductus venosus (D), ductus arteriosus (DA), aorta (A) and caudal vena cava (C).

1

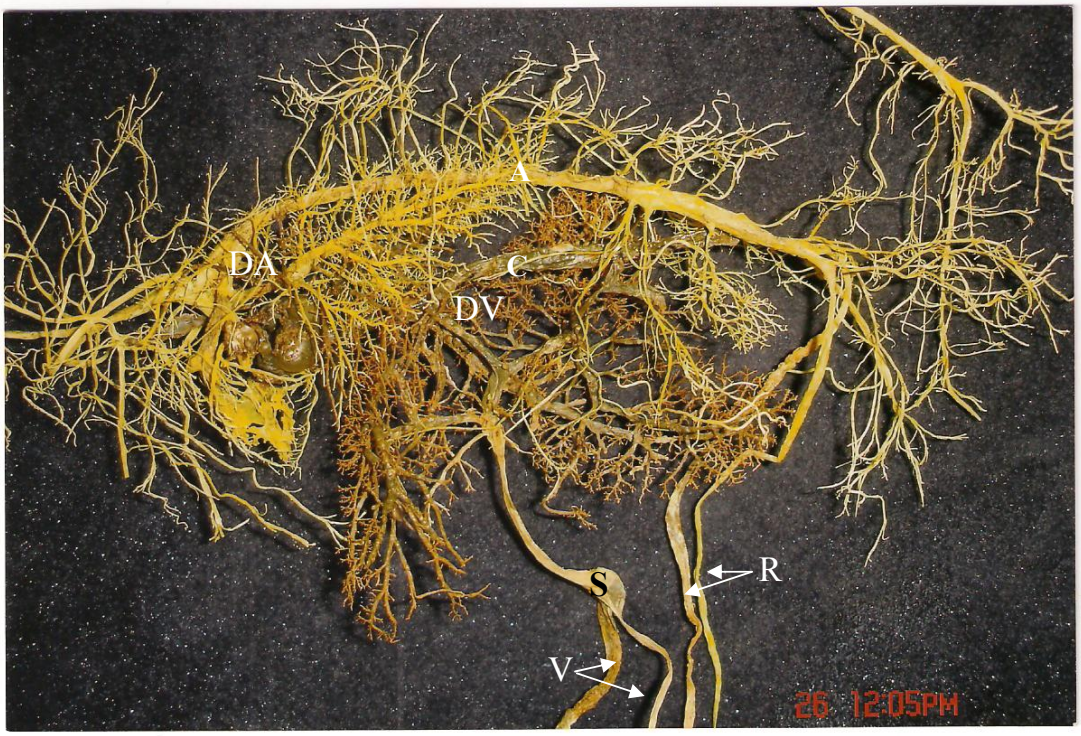

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Fig. 3: Photograph of a part of dissected foetal circulation during first trimester, showing umbilical vein (V), portal vein (P), ductus venosus (DV), heart (H), left kidney (K), liver (L) and caudal vena cava (C).

Fig. 4: Photograph of a foetal cast during second trimester, demonstrating umbilical vein (V) joined by the portal vein (PV) to form ductus venosus (DV). C: caudal vena cava.

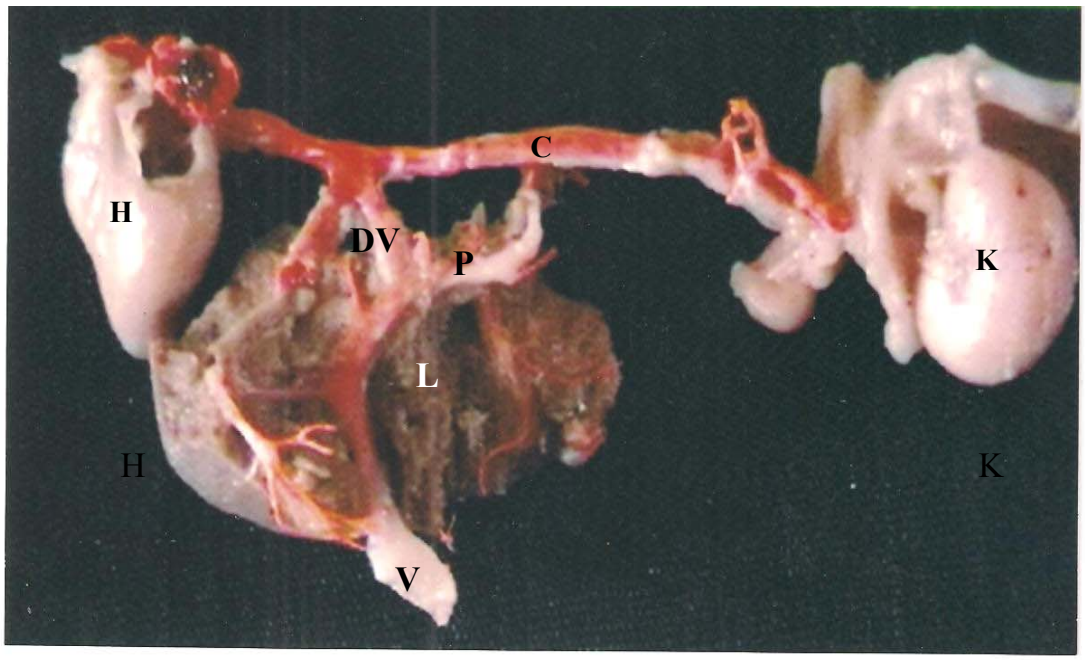

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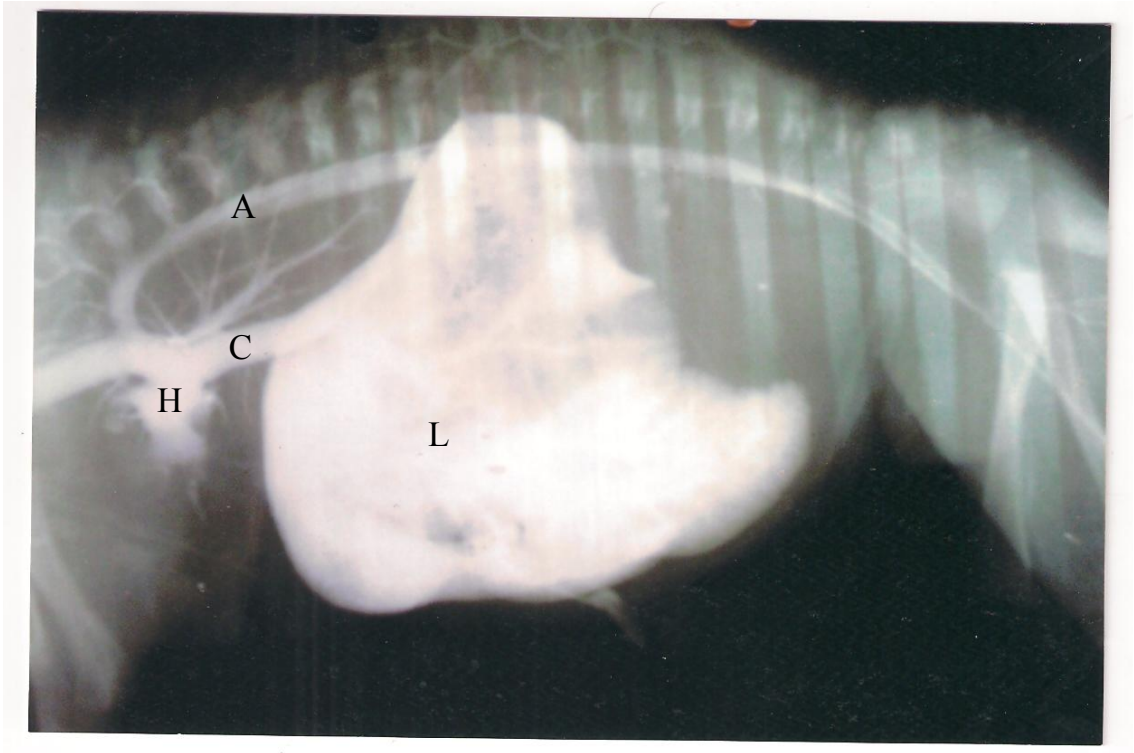
Fig. 5: X-ray Photograph showing blood vessels of a foetus injected with radioopaque material during third trimester. L: liver, heart (H), aorta (A), caudal vena cava (C).

Fig. 6: Photograph of a cross section of an umbilical cord consisting of two umbilical veins, (v), two umbilical arteries (R) and a large allantoic duct (A). The skin (S) covered the proximal part of the umbilical cord near the navel.



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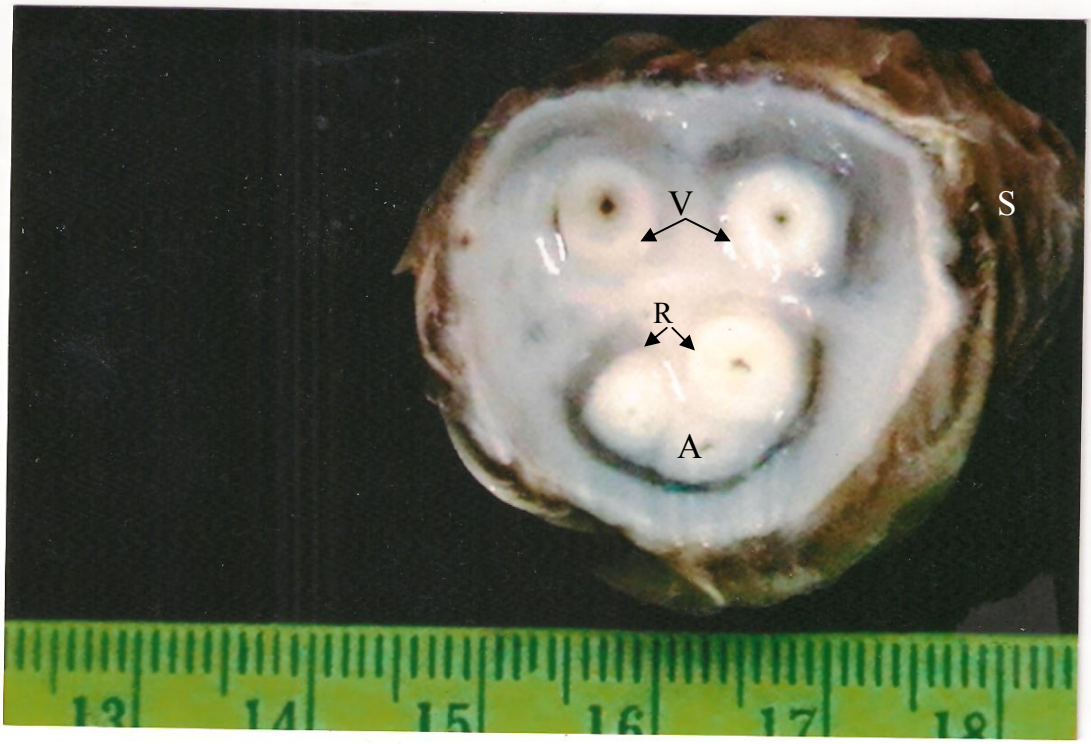

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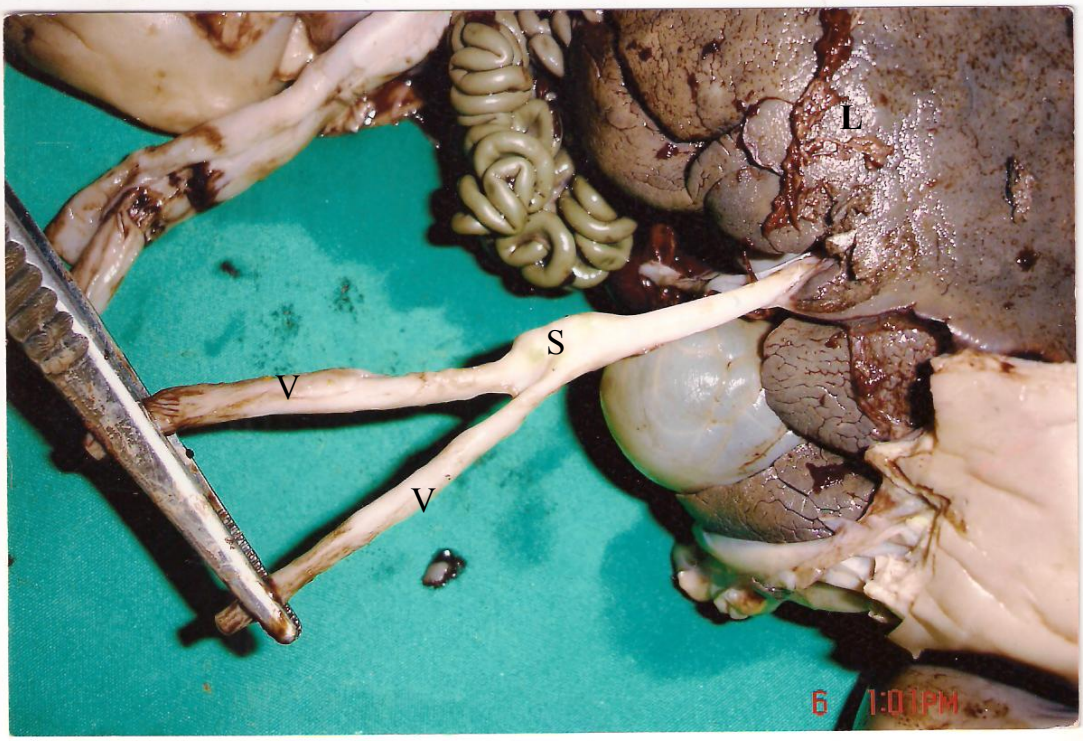
Fig. 7: Photograph showing two umbilical veins (V) uniting in a venous sinus (S), before entering the liver (L) during second trimester.

Fig. 8: Photograph of a foetus demonstrating two umbilical veins (V) which unite within the umbilical cord in a sinus (S) during third trimester. Note the two umbilical arteries (R) and the allantoic duct (A) between the umbilical arteries.



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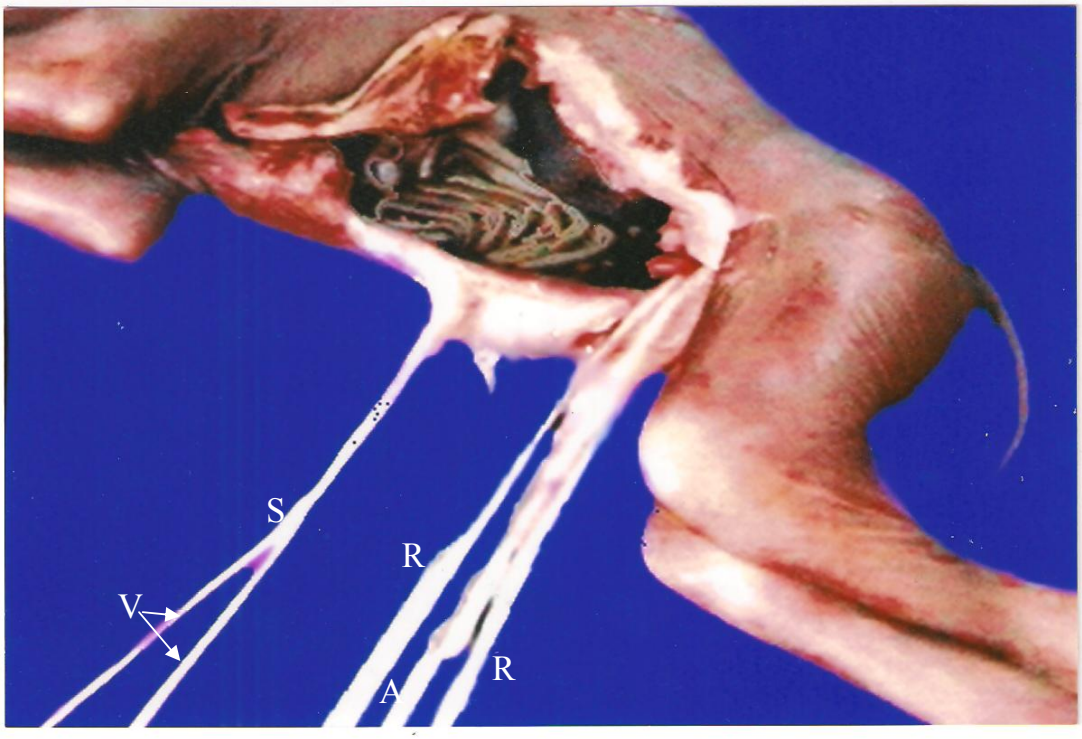

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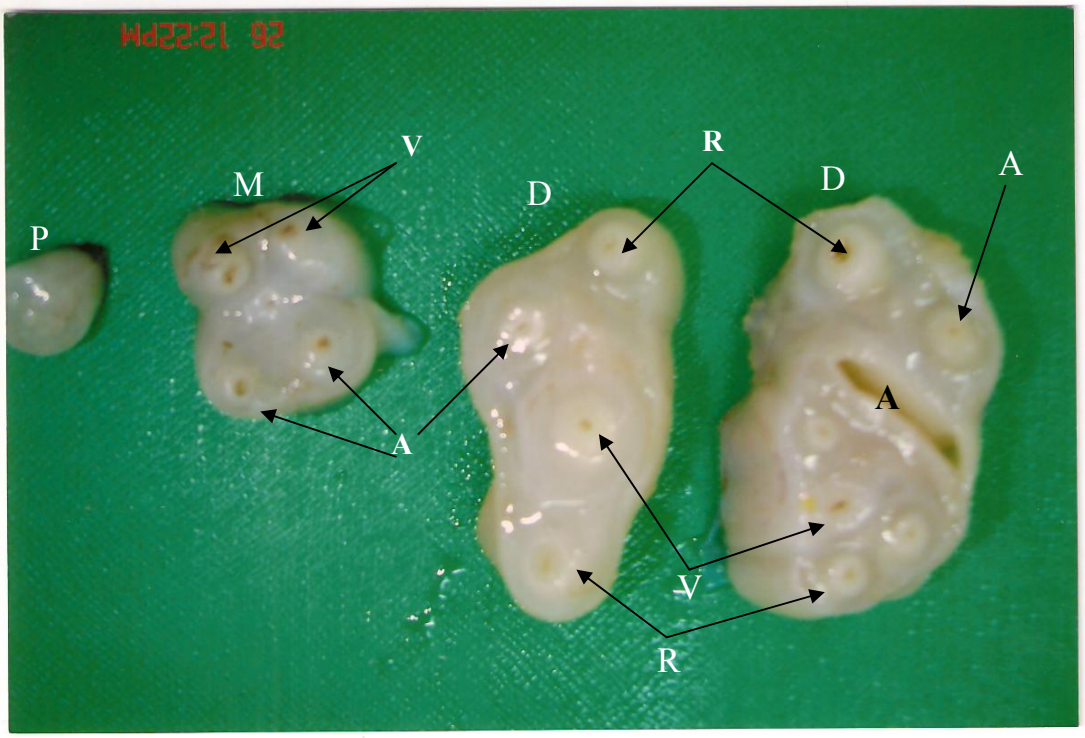
Fig. 9: Photograph showing cross sections of umbilical cords during first trimester at the proximal part (P), at the middle part during second trimester (M) and at the distal part (D) during third trimester of the cord. A: allantoic duct, umbilical arteries (R) and umbilical veins (V).

Fig. 10: Photograph of a cast of foetus during second trimester illustrating umbilical vein (V) uniting with the portal vein (P) to form the ductus senosus (D). Note the candal vena cava (CV) and a branch from the umbilical vein (B).



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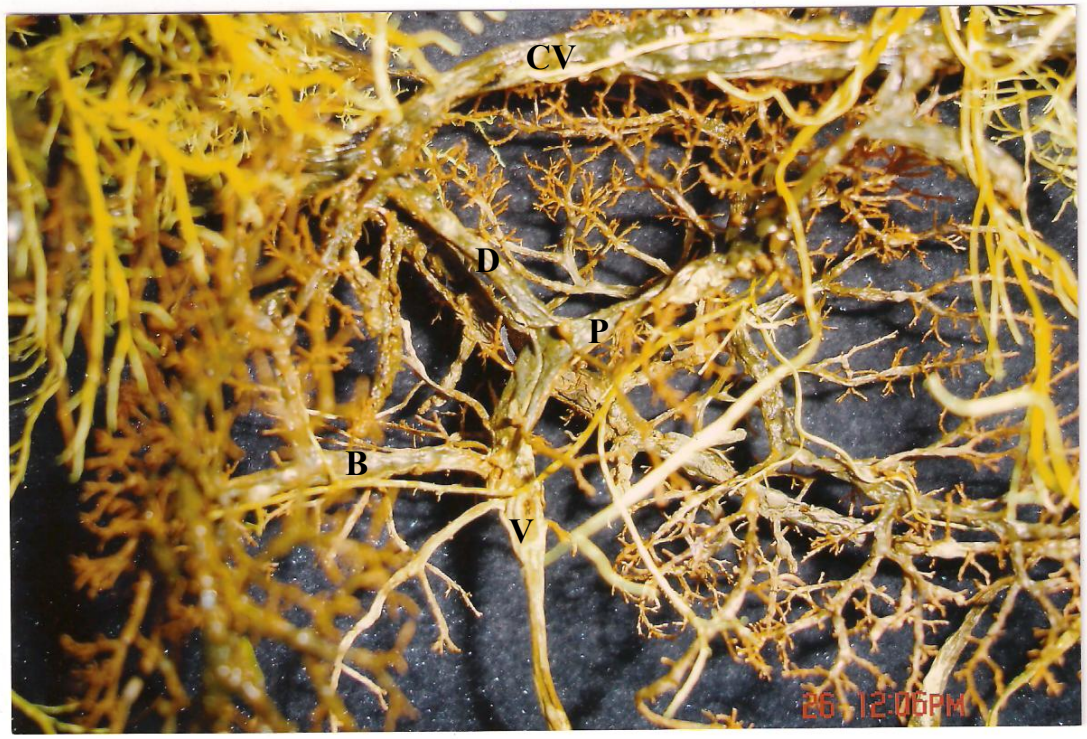

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Fig. 11: Photograph a cast of foetus during second trimester demonstrating pulmonary trunk (PT), pulmonary artery (PA), ductus arteriosus (DA), aorta (A), left subclavian artery (LS) and brachiocephalic trunk (BT).

Fig. 12: Photograph showing the ductus arteriosus (D), pulmonary trunk (PT), pulmonary artery (PA), aorta (A), heart (H), left subclavian artery (LS) and brachiocephalic trunk (BT).

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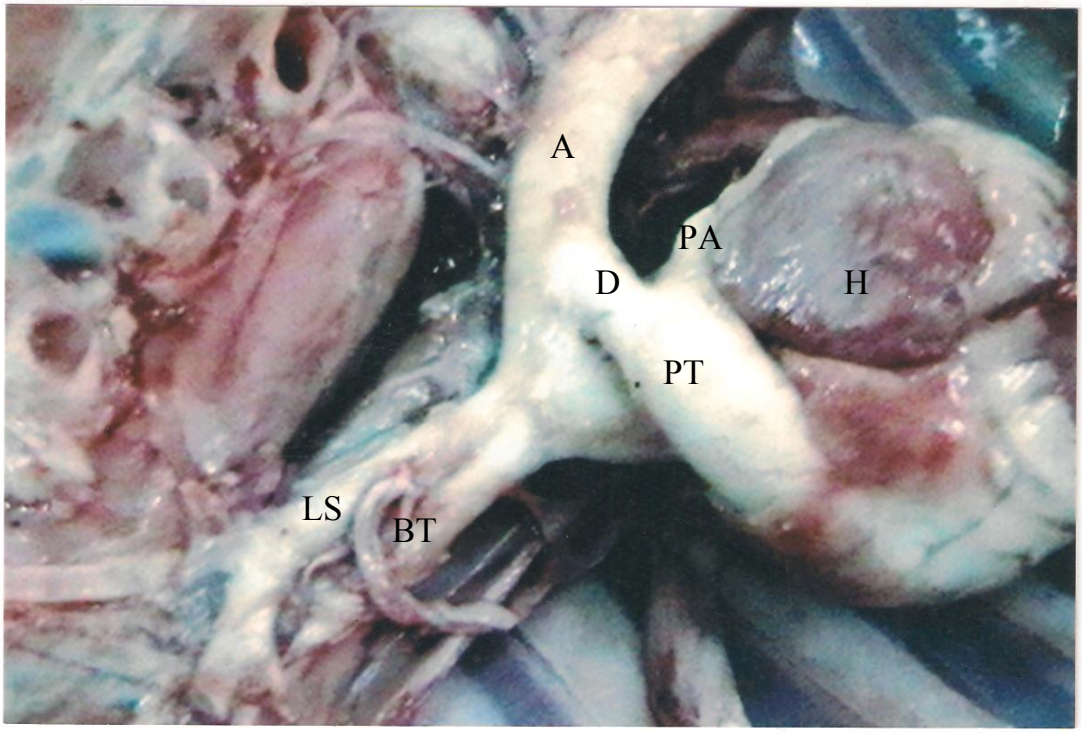

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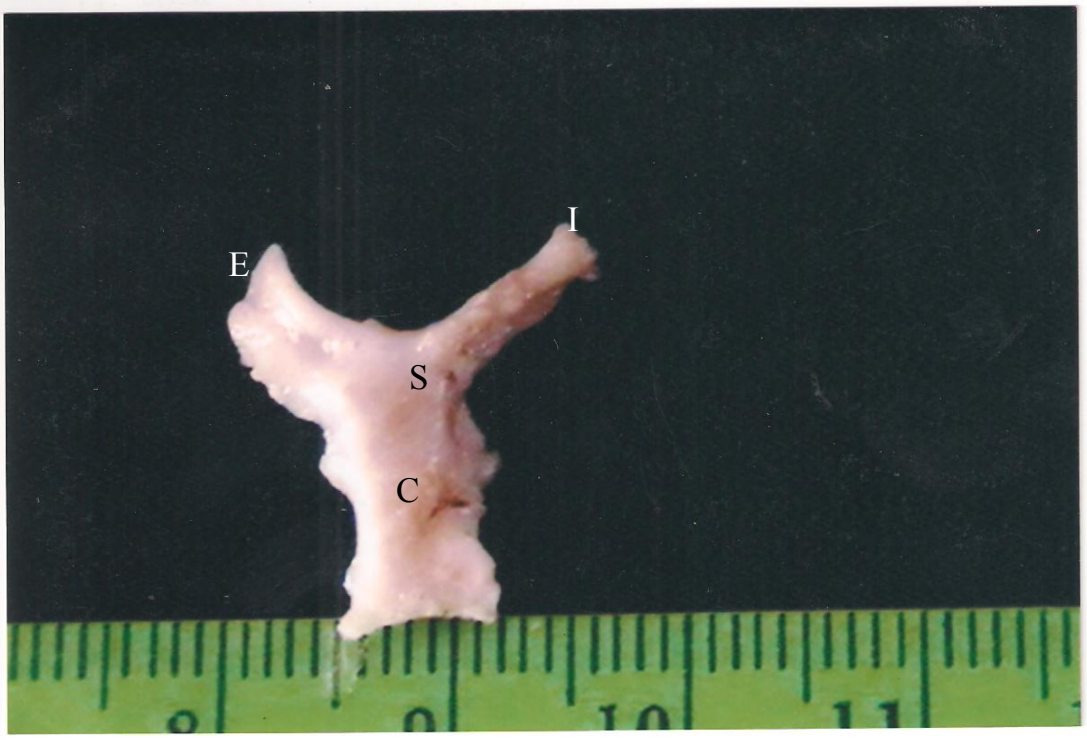
Fig. 13: Photograph showing the common carotid artery (C) and its bifurcation into internal (I) and external (E) carotid arteries and carotid sinus region (S) during third trimester.

Fig. 14: Photograph showing a rudimentary yolk sac in the umbilical cord during first trimester. H and E stain. X 1200.



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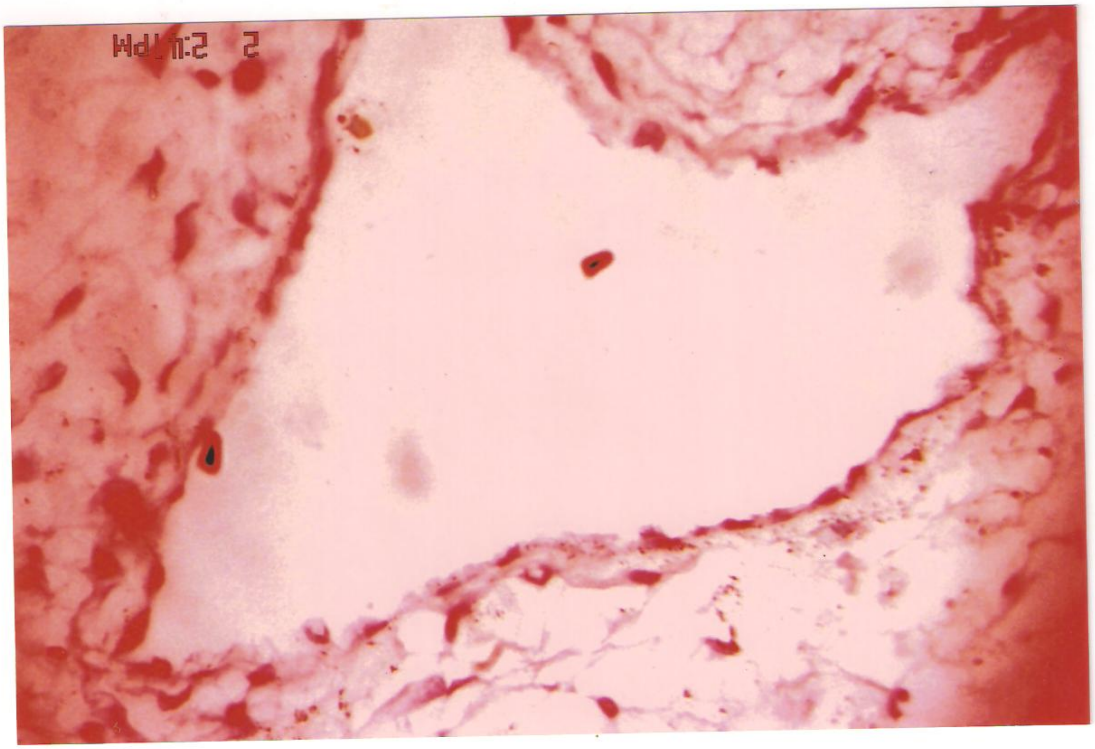
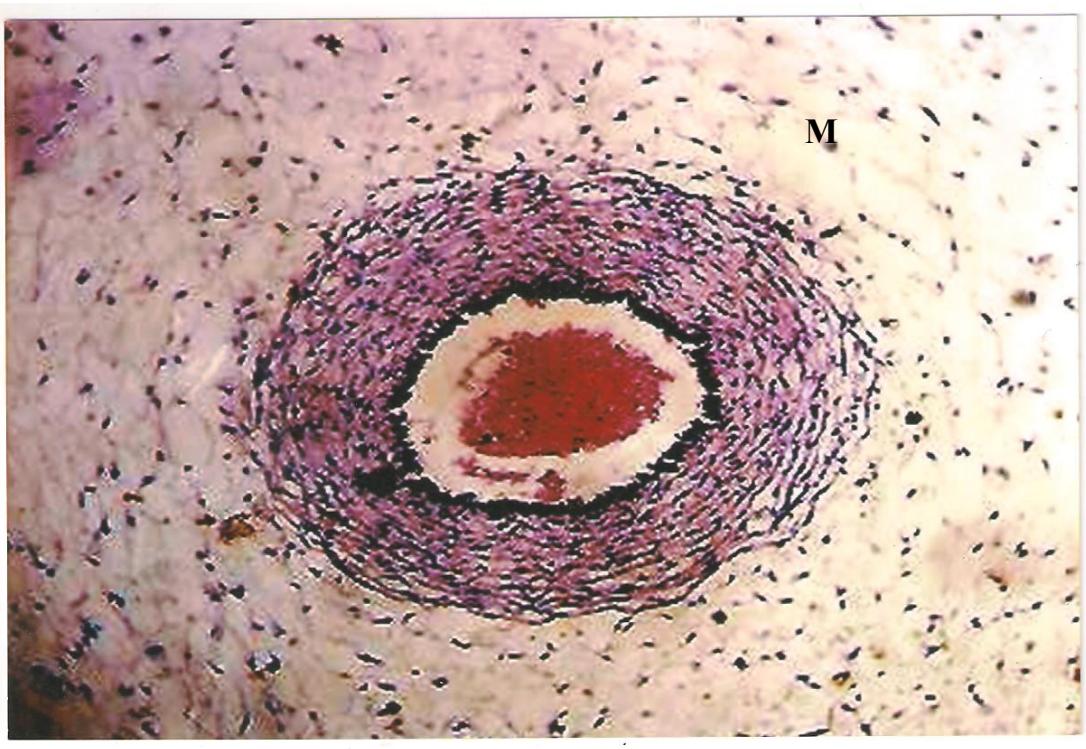


14

Fig. 15: Photograph showing an umbilical artery during first trimester containing smooth muscles fibres (red) and scattered mesenchymal cells (M) in the matrix of the cord. H and E stain. X 300.

Fig. 16: Photograph showing the sinus region at the junction of the two umbilical veins (V) during first trimester. The wall between the two veins was broken (W). H and E stain. X 300.



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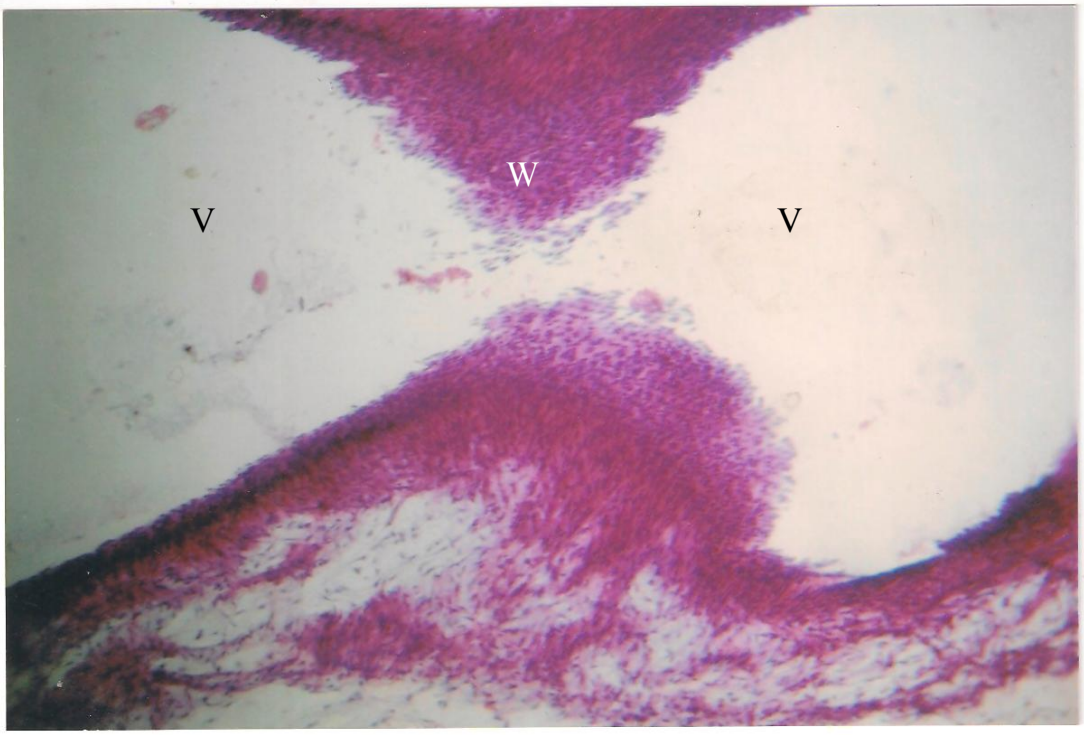

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Fig. 17: Photograph of the sinus region of the two umbilical veins. Note the tunica intima (I) and the media (M) rich in smooth muscle fibres (red) and decrease toward the tunica adventitia (A), during first trimester. H and E stain. X 300.

Fig. 18: Photograph showing an allantoic duct transitional epithelium (arrows), during first trimester. Masson´s Trichrome stain. X 1200.

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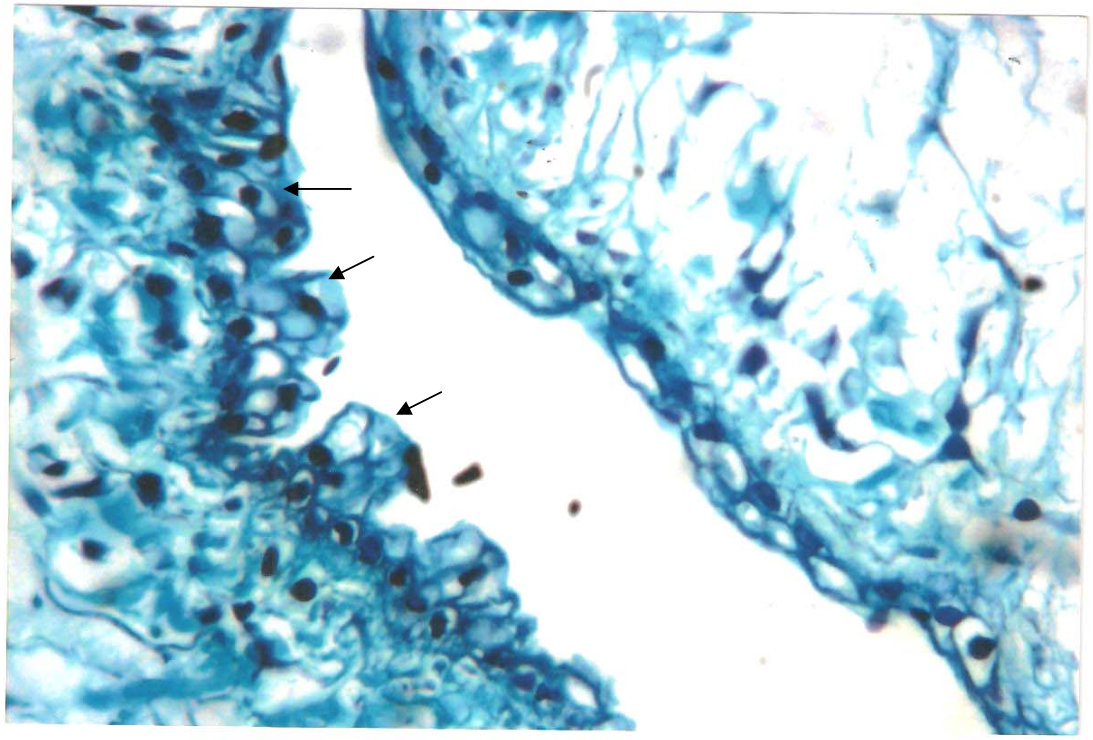
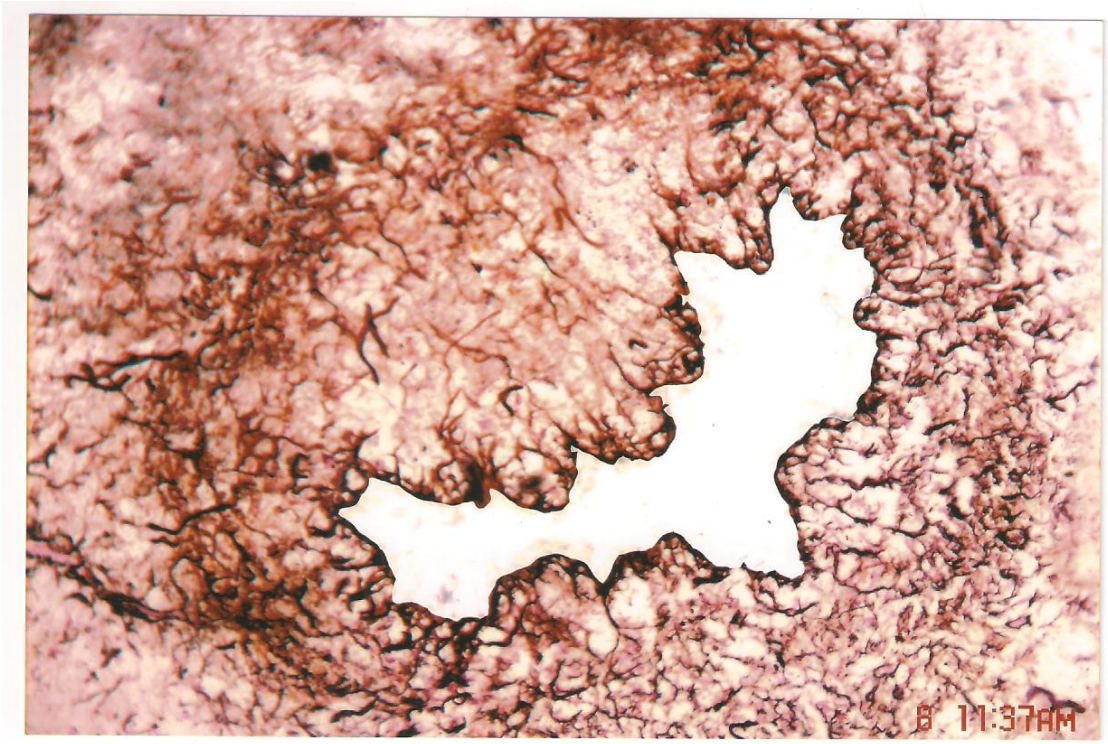


18

Fig. 19: Photograph showing elastic fibres (black) in the wall of the allntoic duct, during first trimester. Verhoelff's stain. X 1200.

Fig. 20: Photograph of ductus venosus (DV) during first trimester at the junction with vena cava demonstrating many nerve fibres (N). H: hepatic vein. Verhoeff's stain. X 300.



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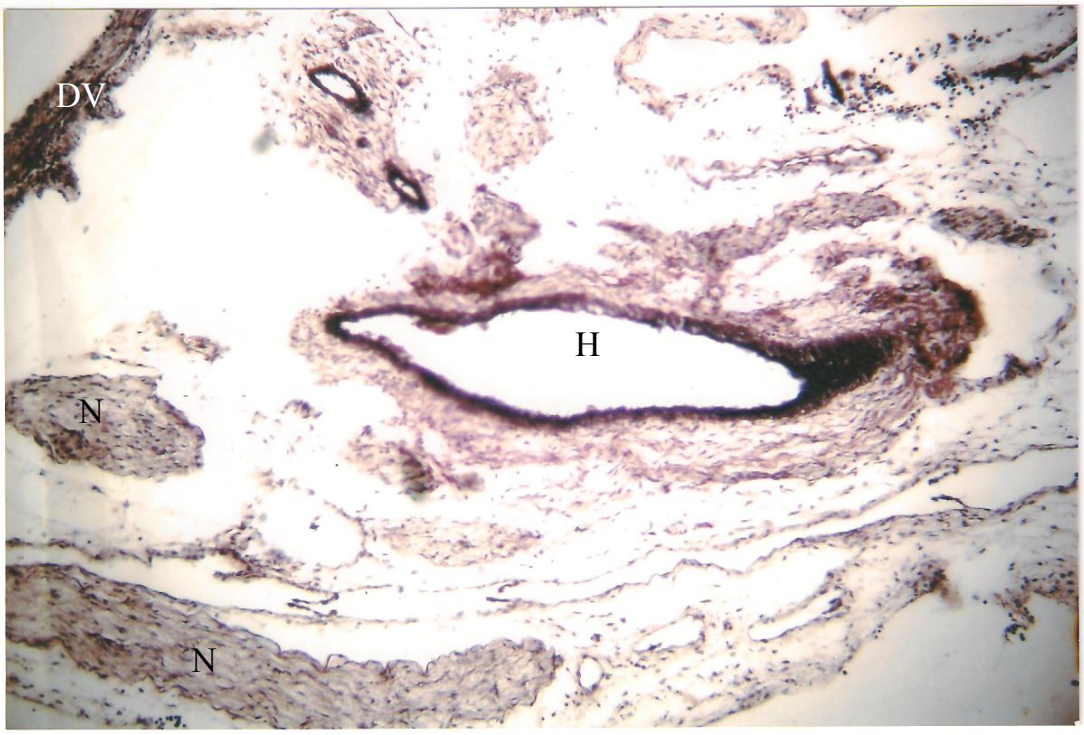
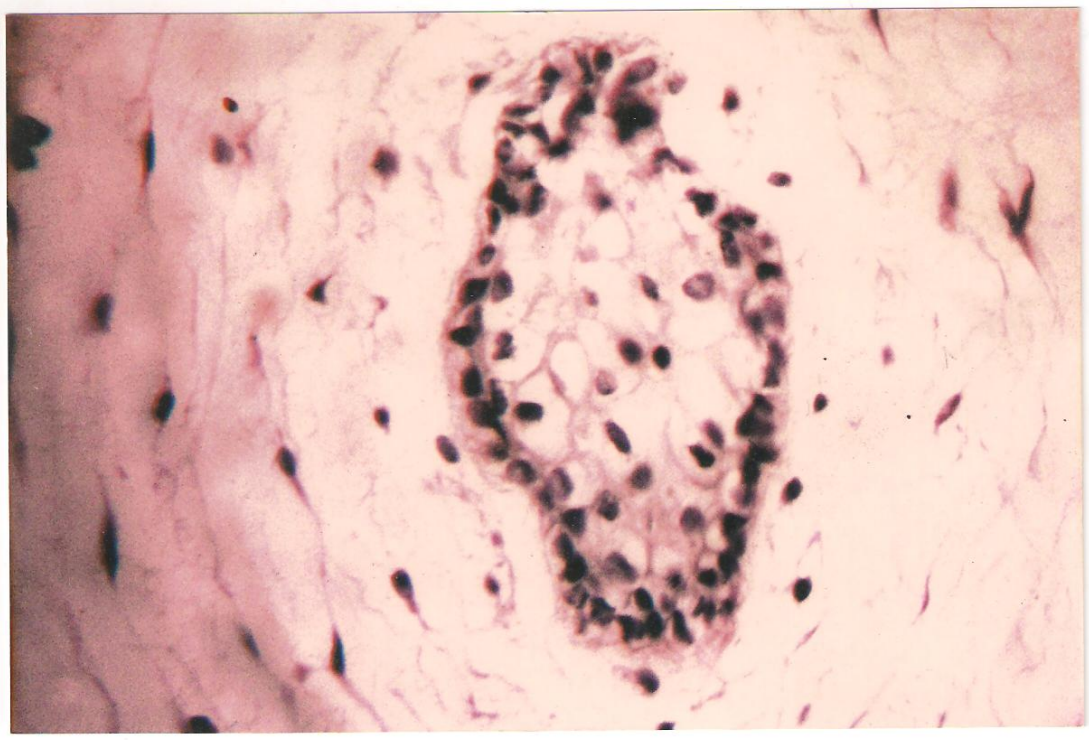


20

Fig. 21: Photograph showing a mass of cells in the umbilical cord during second trimester. The rounded pale cells are covered by cuboidal cells and mesenchymal cells surround the mass. H and E stain. X 1200.

Fig. 22: Photograph showing a mass of cells in the umbilical cord near the allantoic duct during second trimester. Aldehyde Fuchsin stain. X 1200.



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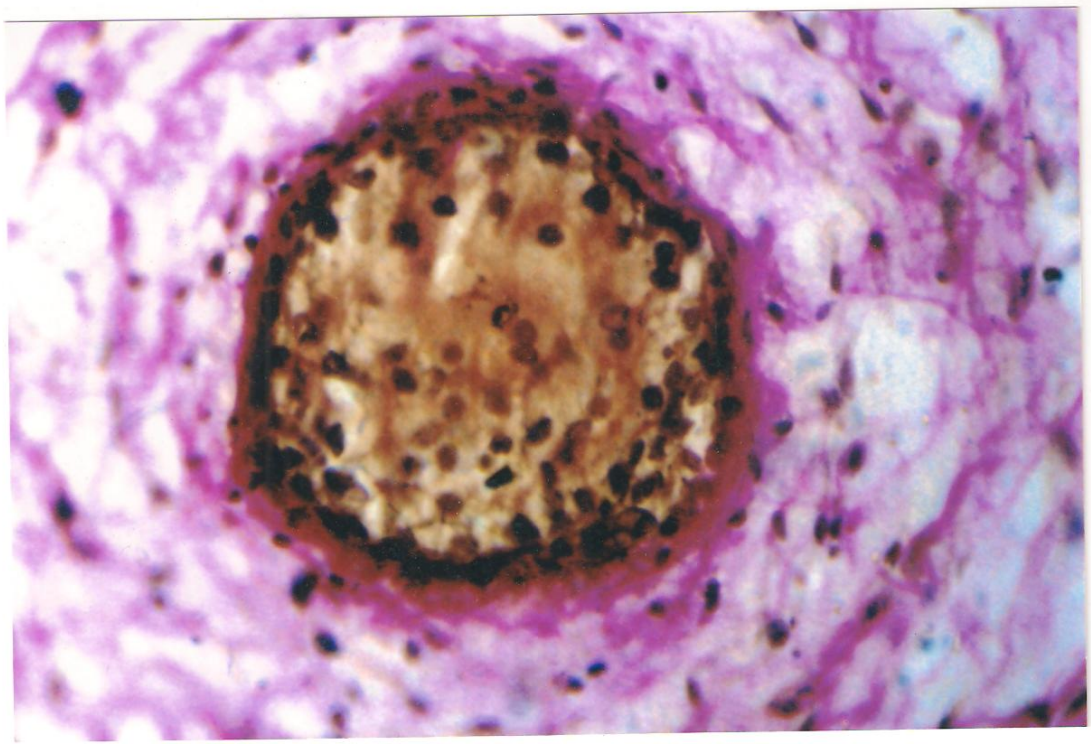
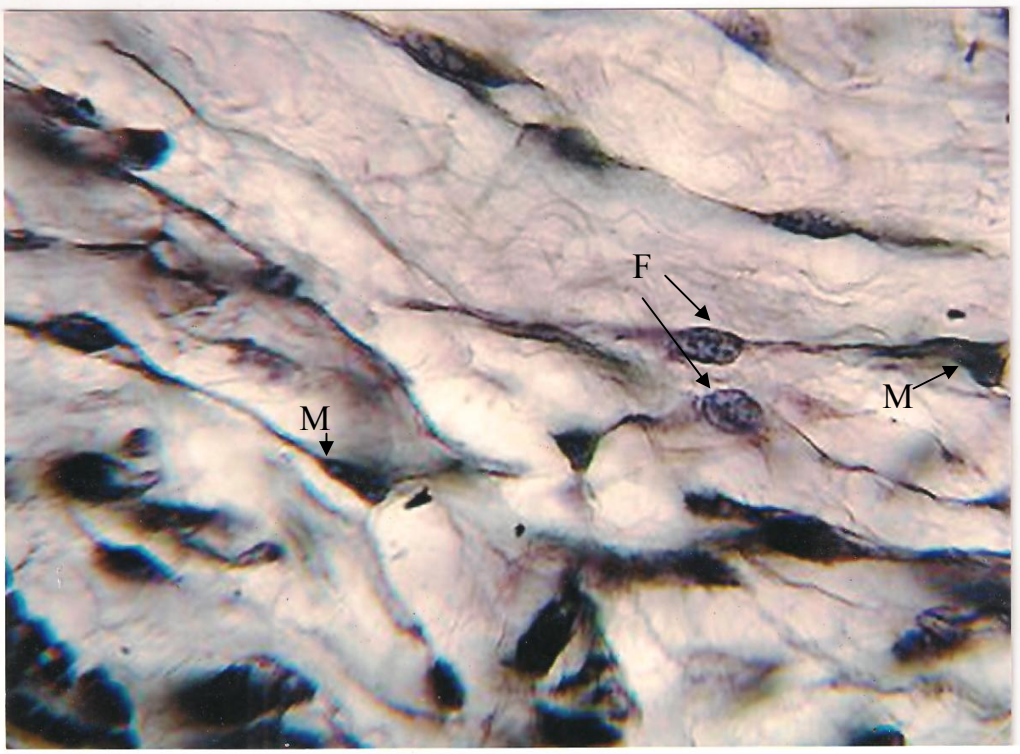


22

Fig. 23: Photograph showing mesenchymal cell (M), fibroblasts (F) in the matrix of the umbilical cord during second trimester. Orcein stain. X 1200.

Fig. 24: Photograph showing part of amnion membrane (A) with projection (P) covering the umbilical cord (C). Note the loose connection between them (asterisks) during second trimester. Aldehyde Fuchsin stain. X 1200.



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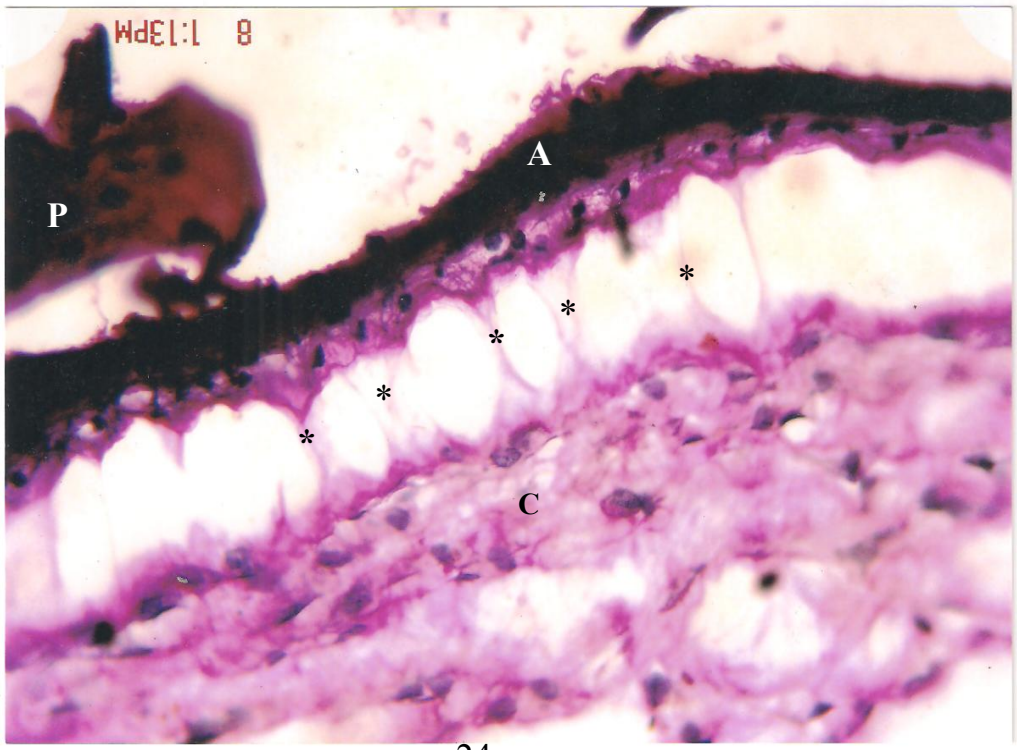

24

Fig. 25: Photograph of an arteriole in the umbilical cord during second trimester. Note the presence of lightly stained groups of cells (C). Aldehyde Fuchsin stain. X 1200.

Fig. 26: Photograph of an umbilical cord at its proximal part (near the navel) during second trimester. Note the epidermis (E), the dermis (D) and elastic fibres in the form of a large strand (S) separating the skin from the cord matrix. Aldehyde Fuchsin with Van Gieson as counter stain. X 120.

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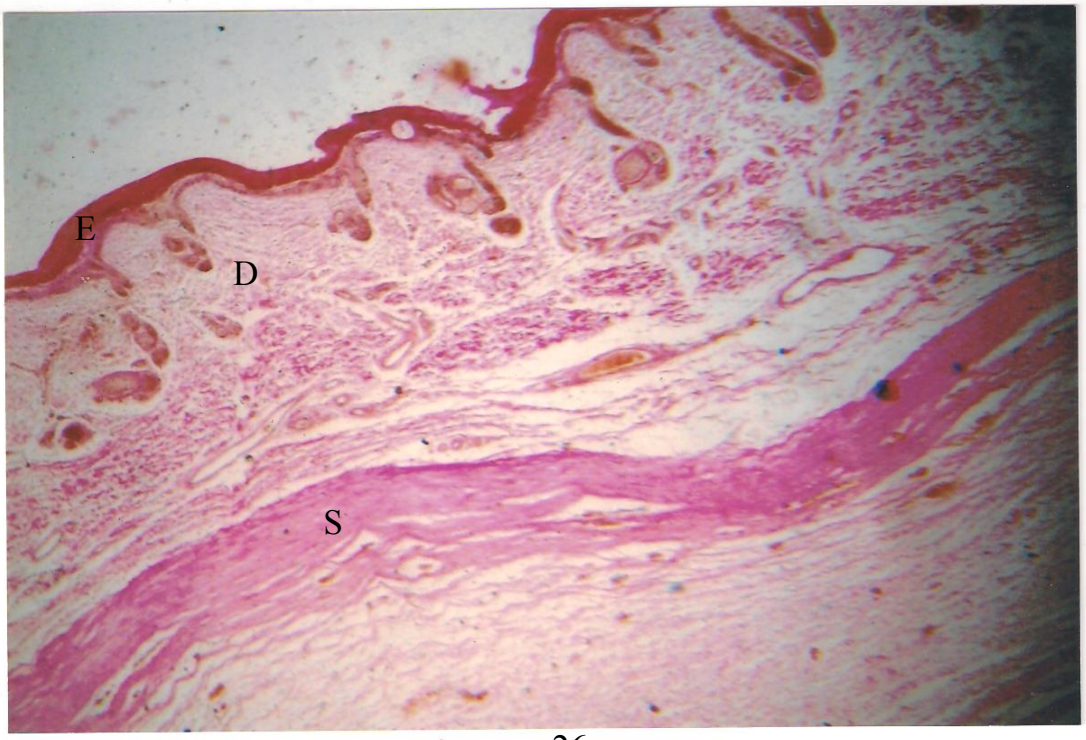

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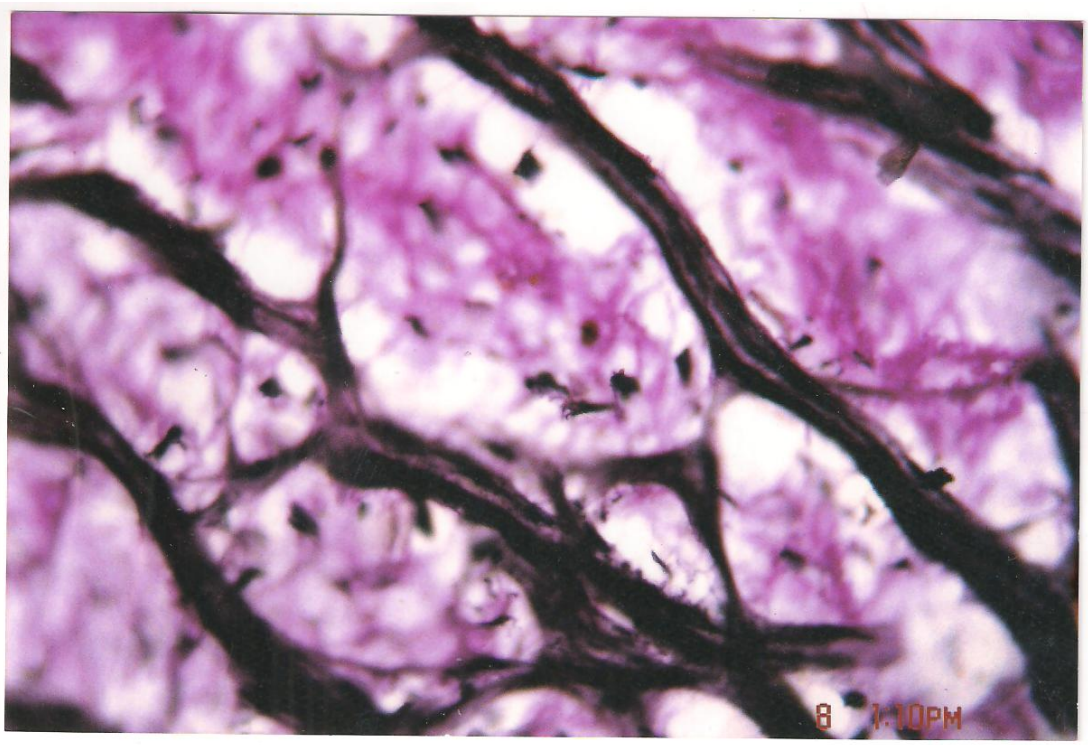
Fig. 27: Photograph showing branched and anastomosed smooth muscle fibres in the wall of the umbilical artery, during second trimester. Aldehyde Fuchsin stain. X 1200.

Fig. 28: Photograph showing branched and anastomosed smooth muscle fibres in the wall of the umbilical artery, during second trimester. Van Gieson stain. X 1200.



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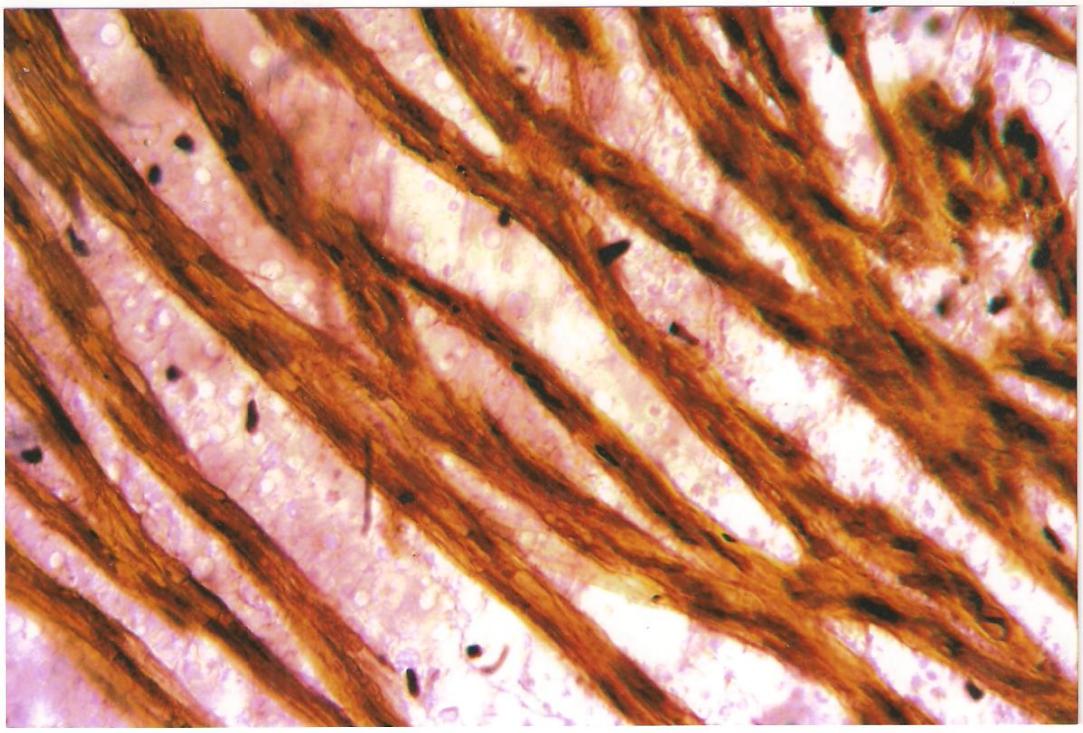
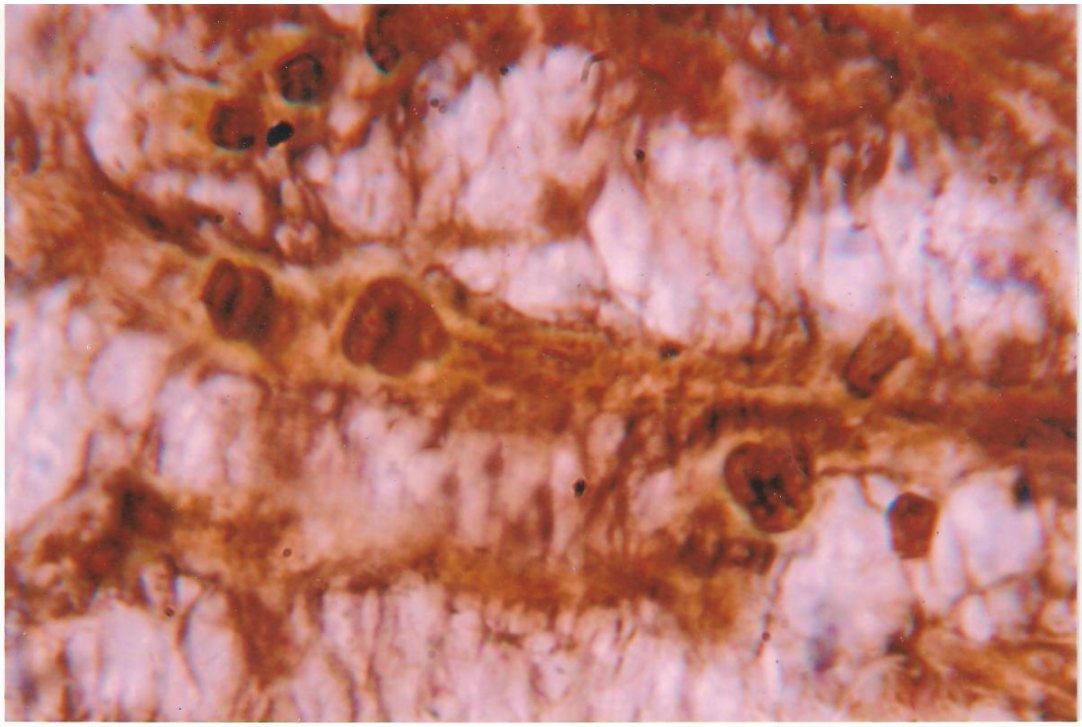


28

Fig. 29: Photograph showing smooth muscle fibers in the umbilical vein during second trimester. Note the spherical nuclei in the thick anastomosed muscle fibres. Van Gieson stain. X 3000.

Fig. 30: Photograph showing an umbilical artery (A) and an umbilical vein (V) during second trimester. Note the regular lumen of umbilical vein. H and E stain. X 300.



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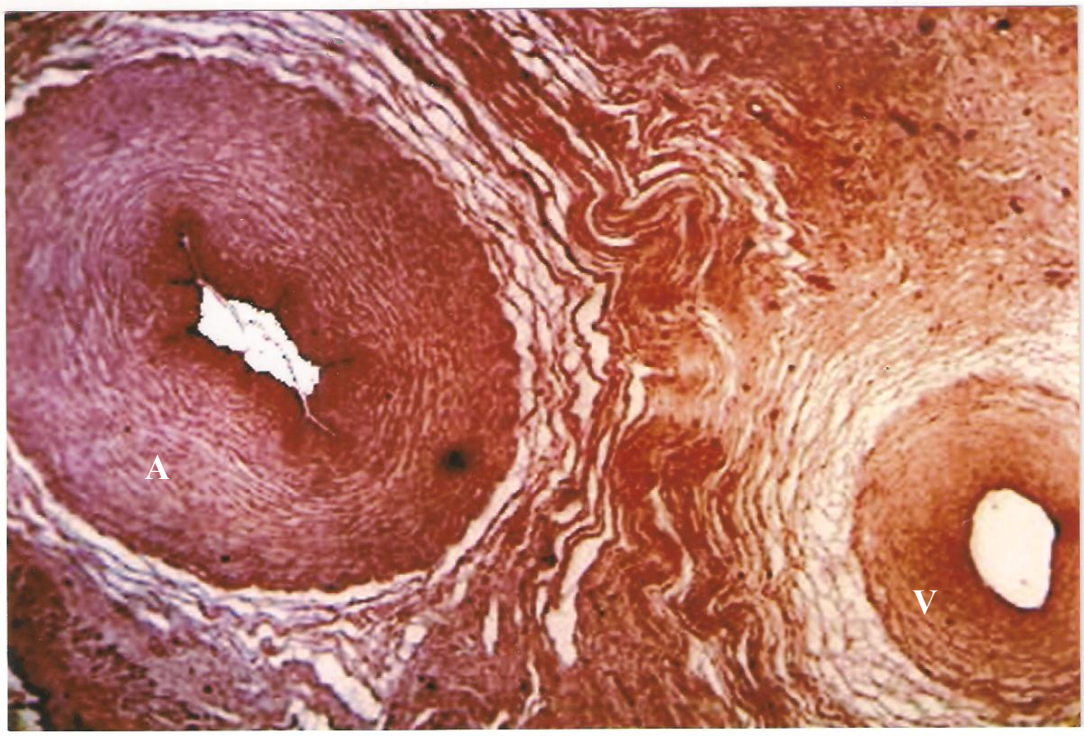

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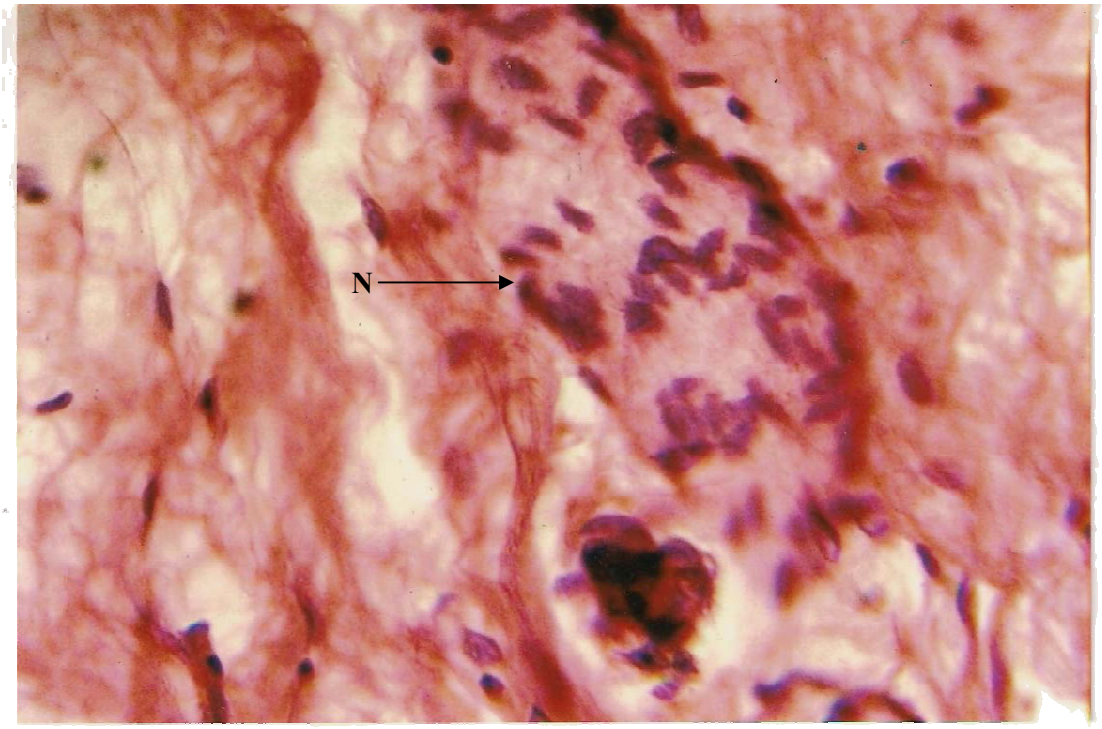
Fig. 31: Photograph showing nerve fibres in the adventitia of a sinus region of the two umbilical vein during second trimester. N: nerve fibres. H and E stain. X 1200.

Fig. 32: Photograph showing an allantoic duct with stratified transitional epithelium (E) and subepithelial layer (S) of mesenchymal cells during second trimester. Massan´s Trichrome stain. X 1200.



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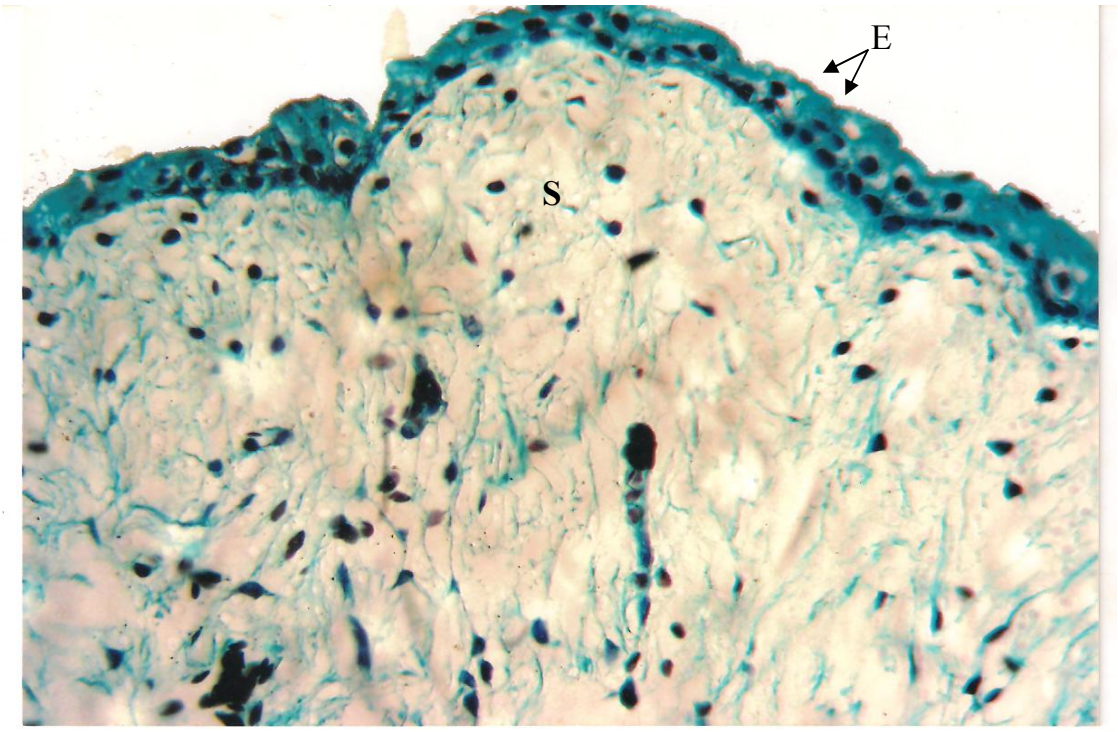

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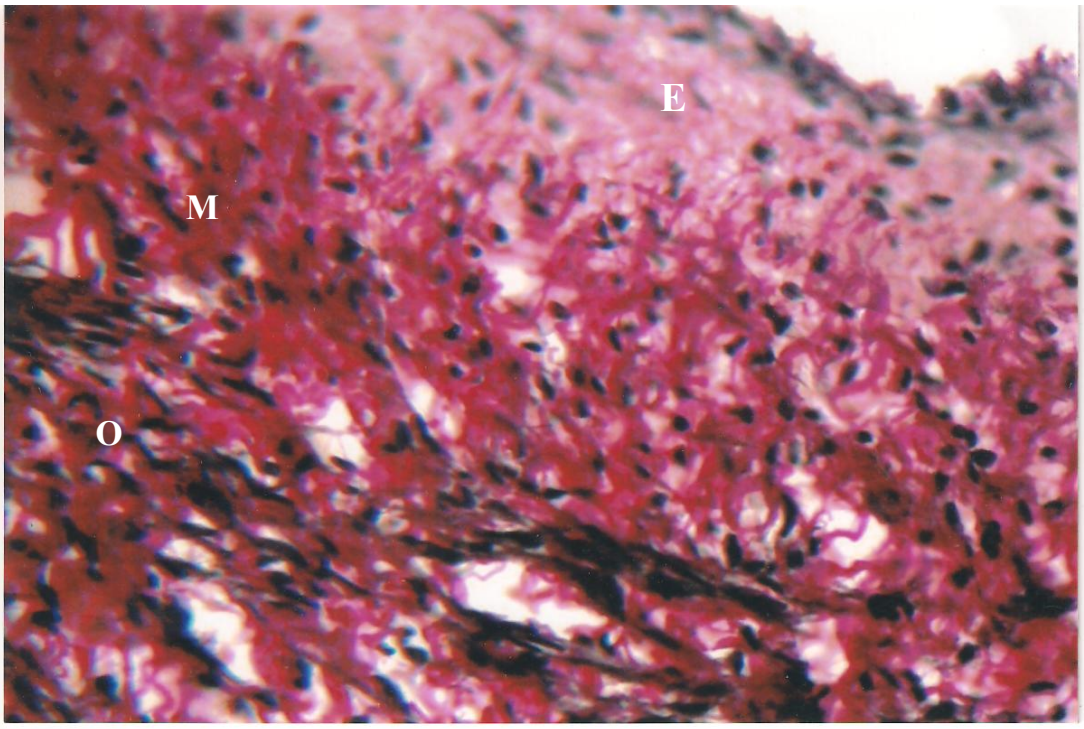
Fig. 33: Photograph of ductus venosus wall illustrating the tunica intima (E), tunica media (M), tunica adventitia (O), the elastic fibres (purple) and smooth muscle (brown) during second trimester. Aldhyde Fuchsin stain with Van Gieson as counter stain. X 1200.

Fig. 34: Photograph of ductus arteriosus (DA) within the aortic wall (A). Note the elastic fibres (black) are more in the aortic wall than in duct arteriosus during second trimester. L: lumen of ductus arteriosus. Verhoeff´s stain with Eosin as counter stain. X 300.



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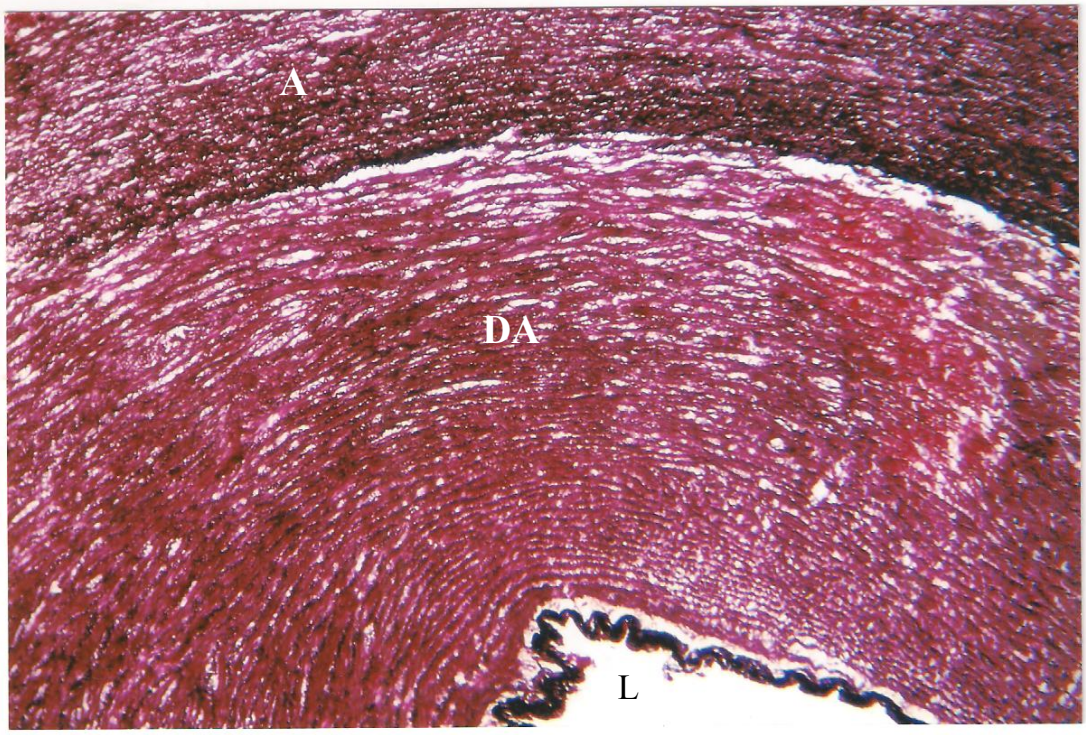

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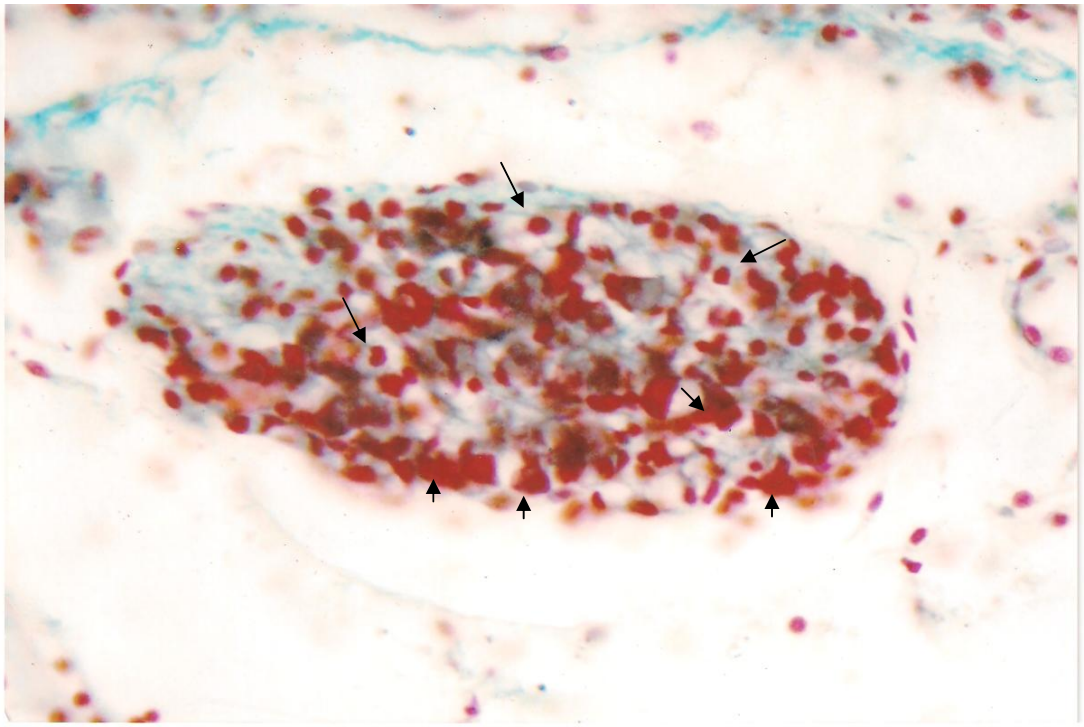
Fig. 35: Photograph of an aortic body in the adventitia of the aorta during second trimester. Note type I cells with regular boundaries (arrow) and type II cell with irregular boundaries (arrow head). Masson′s Trichrome stain. X 300

Fig. 36: Photograph showing an aortic body (A) within the aortic wall and nerve fibres (N), during second trimester. Masson′s Trichrome stain. X 120.



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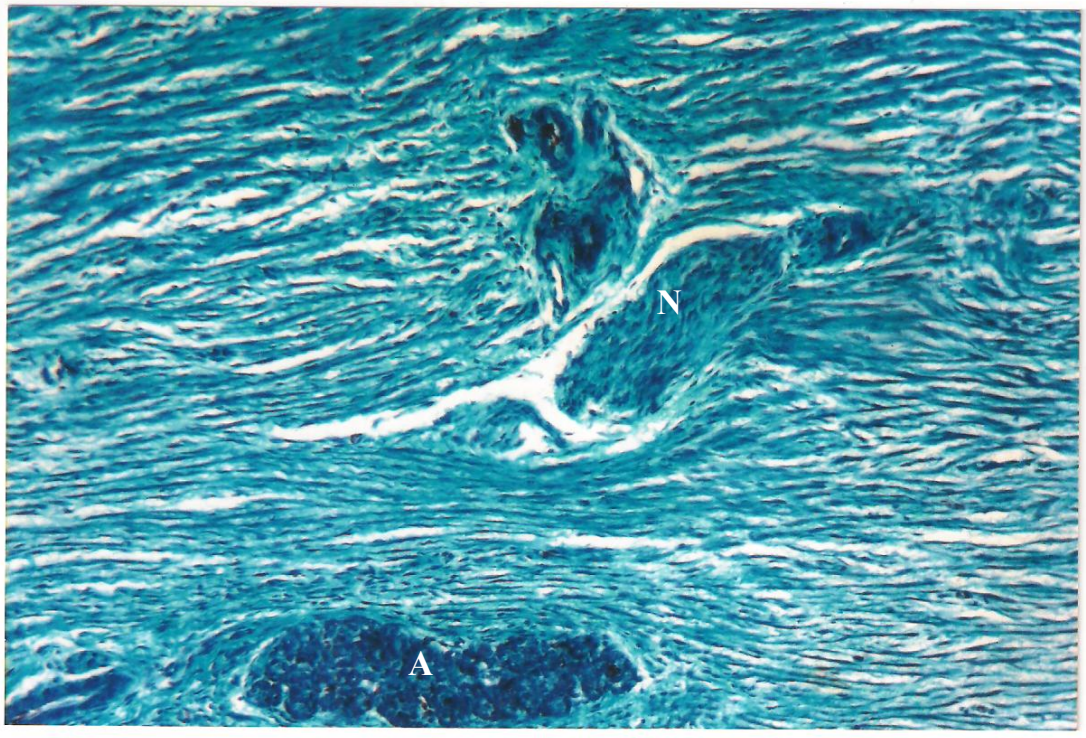

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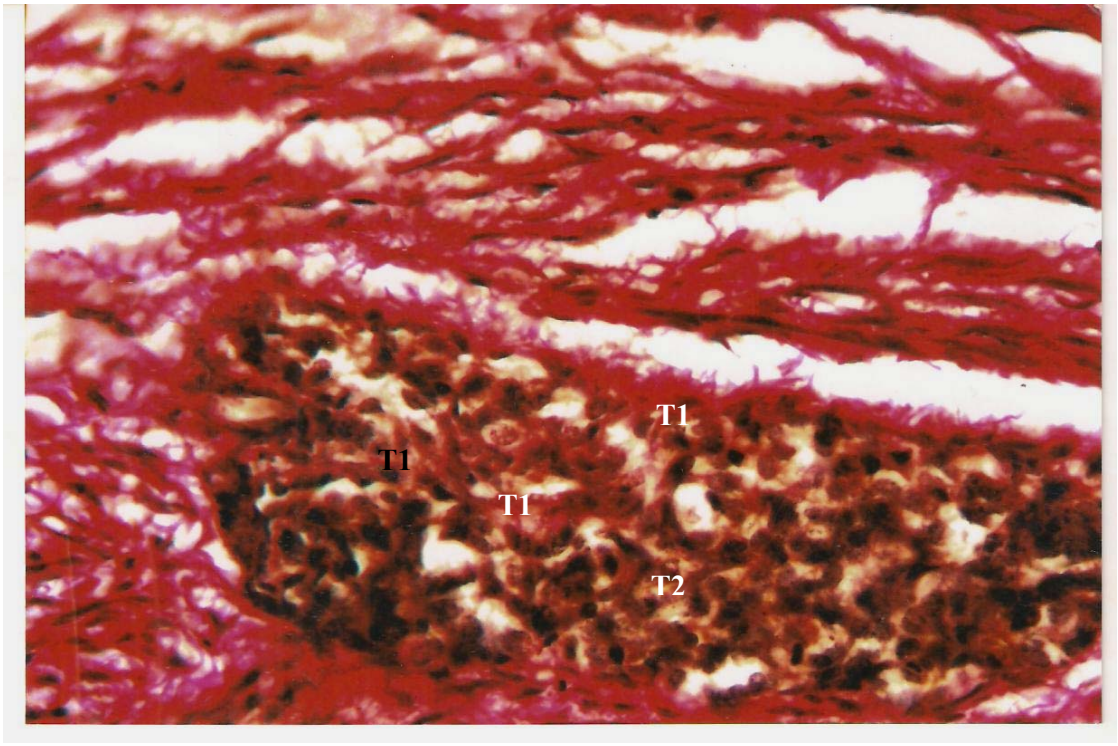
Fig. 37: Photograph of an aortic body within the aortic wall during second trimester. Type I cell (T1) are pale while type II cells are dark (T2), during second trimester. Van Gieson stain. X 300.

Fig. 38: Photograph of an aortic body surrounded with capsule (S) and containing type I cell (T1), type II cell (T2) and capillaries (C), during second trimester. Masson´s Trichrome stain. X 1200.



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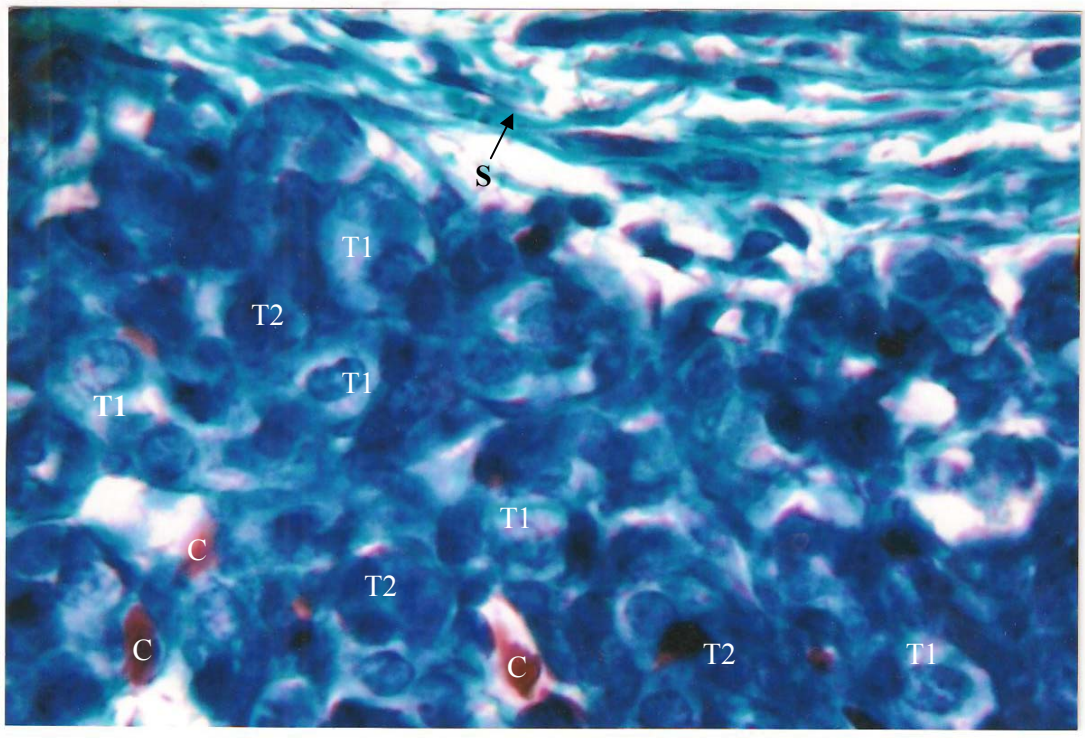

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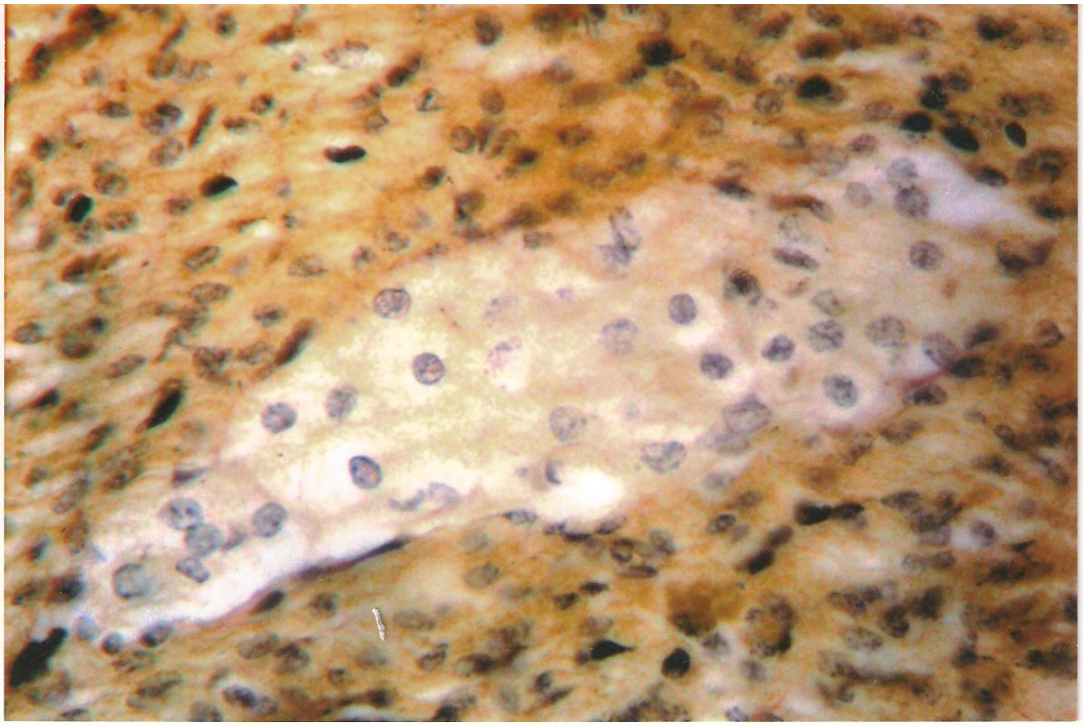
Fig. 39: Photograph of a paraaortic body containing the pale stained cells embedded within the cardiac muscle during second trimester. Van Gieson stain. X 1200.

Fig. 40: Photograph showing a paraaortic body with the pale stained cells within the cardiac muscle, during second trimester, H and E stain. X 1200.



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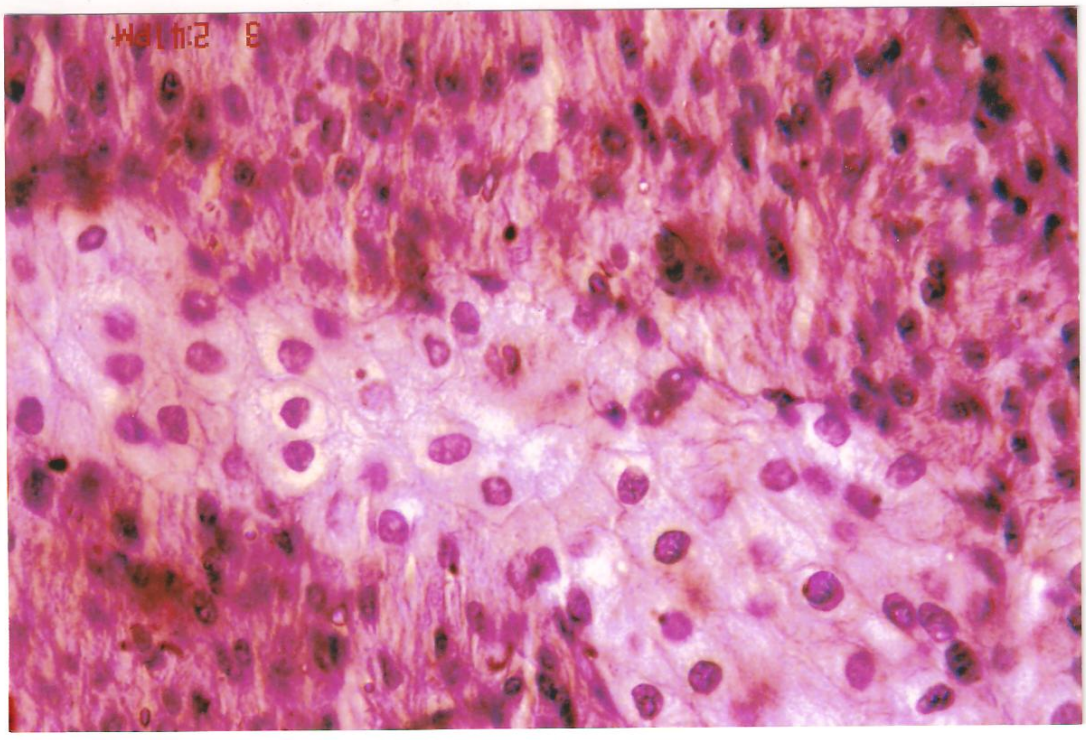

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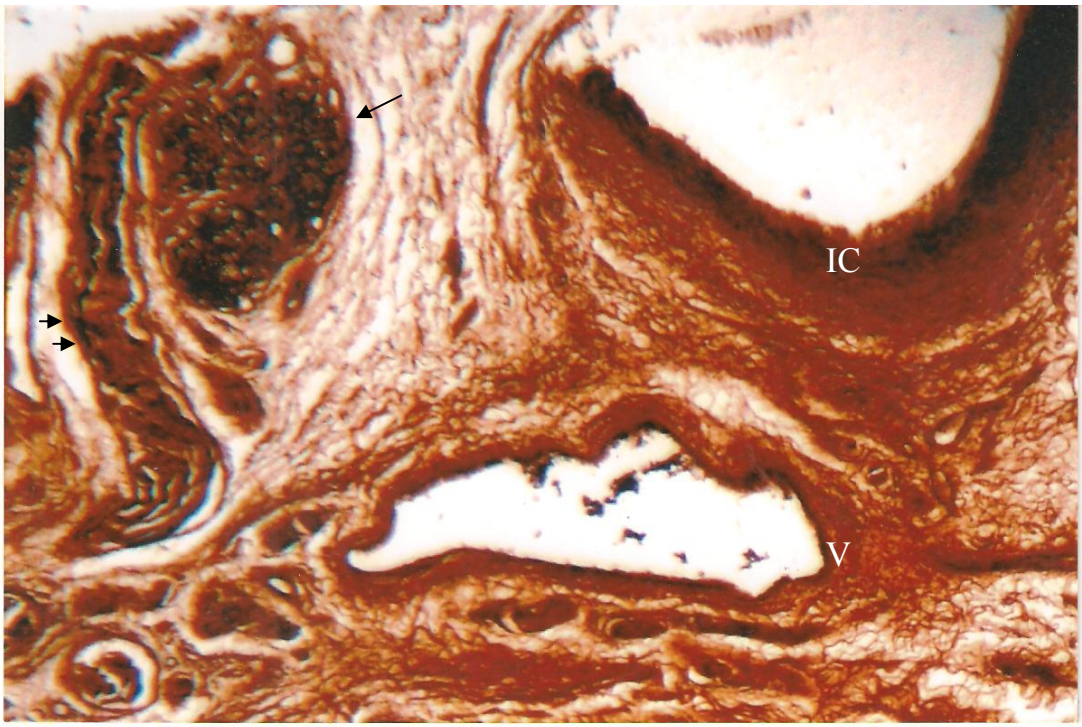
Fig. 41: Photograph showing a carotid body (arrow), internal carotid artery (IC) and nerve fibres (arrow heads) during second trimester. V: vein. Verhoeff's stain. X 300

Fig. 42: Photograph showing carotid bodies (arrows) and nerve fibres (arrow heads), during second trimester. H and E stain. X 300.



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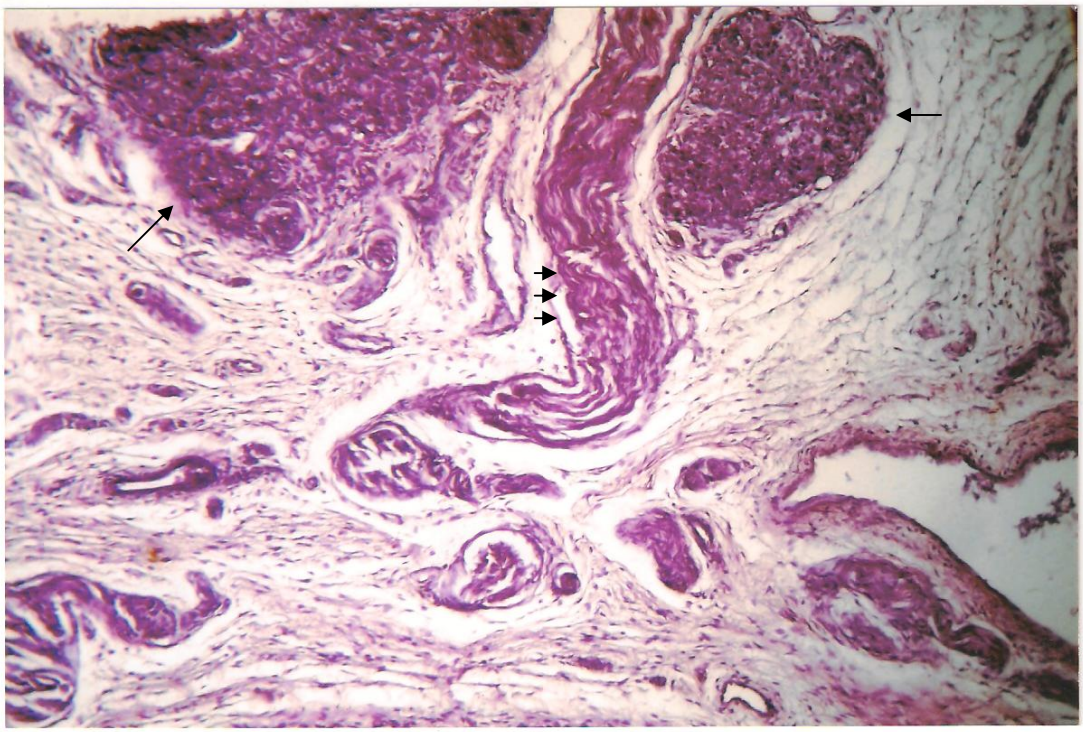
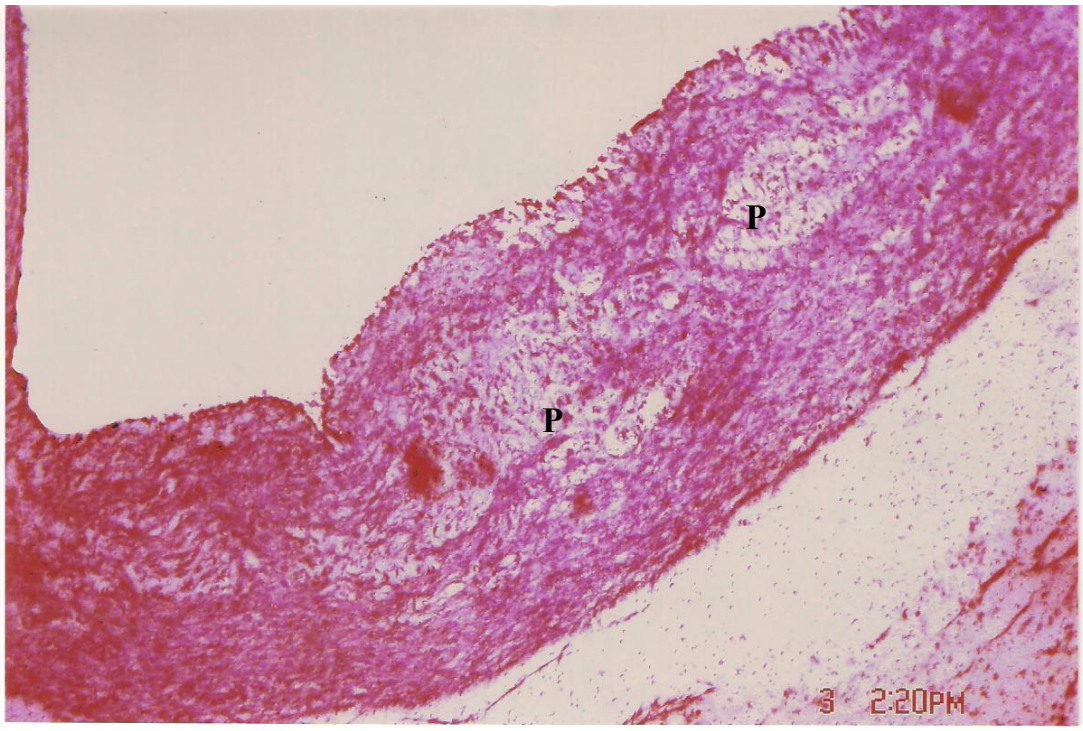


42

Fig. 43: Photograph of the wall of aortic sinus during second trimester. Note the pale stained areas (P). H and E stain. X 300.

Fig. 44: Photograph showing the carotid sinus (S) at the bifurcation of common carotid artery (C) into internal carotid artery (I) and external carotid artery (E). Second trimester. H and E stain. X 300.



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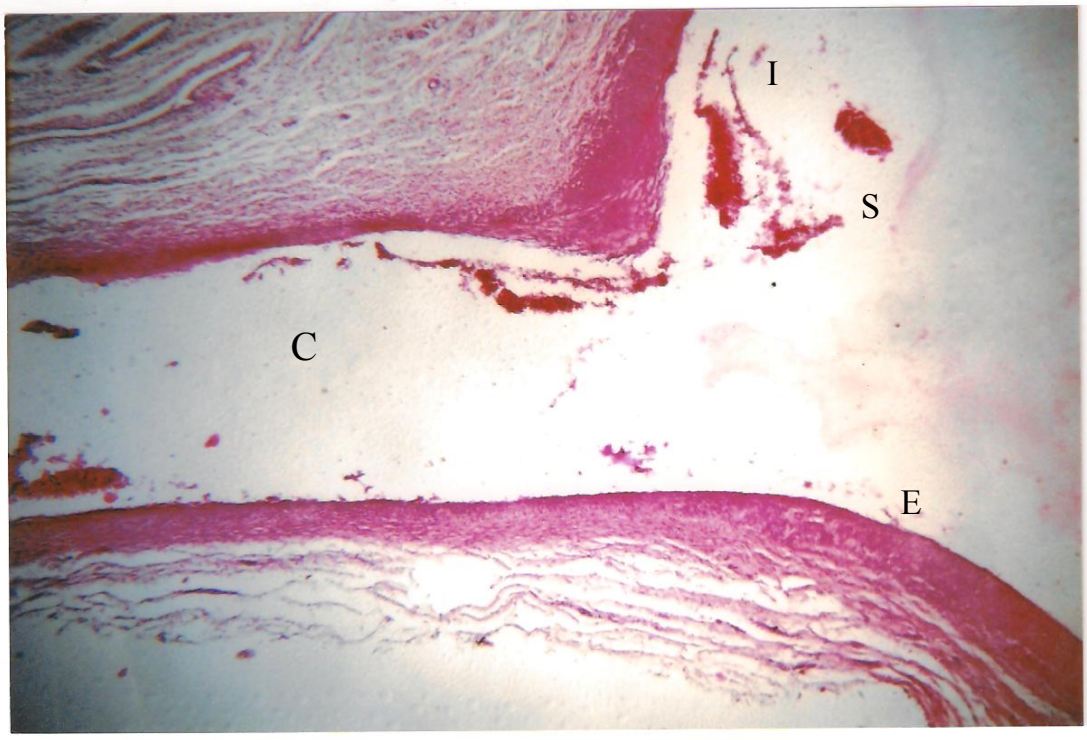

44

Fig. 45: Photograph of the venous sinus region of the two umbilical veins during third trimester. Note the elongated nuclei of the smooth muscle fibres. H and E stain. X 1200.

Fig. 46: Photograph showing an allantoic duct with elastic fibres (black) underling the epithelium during third trimester. Verhoeff's stain. X 300.

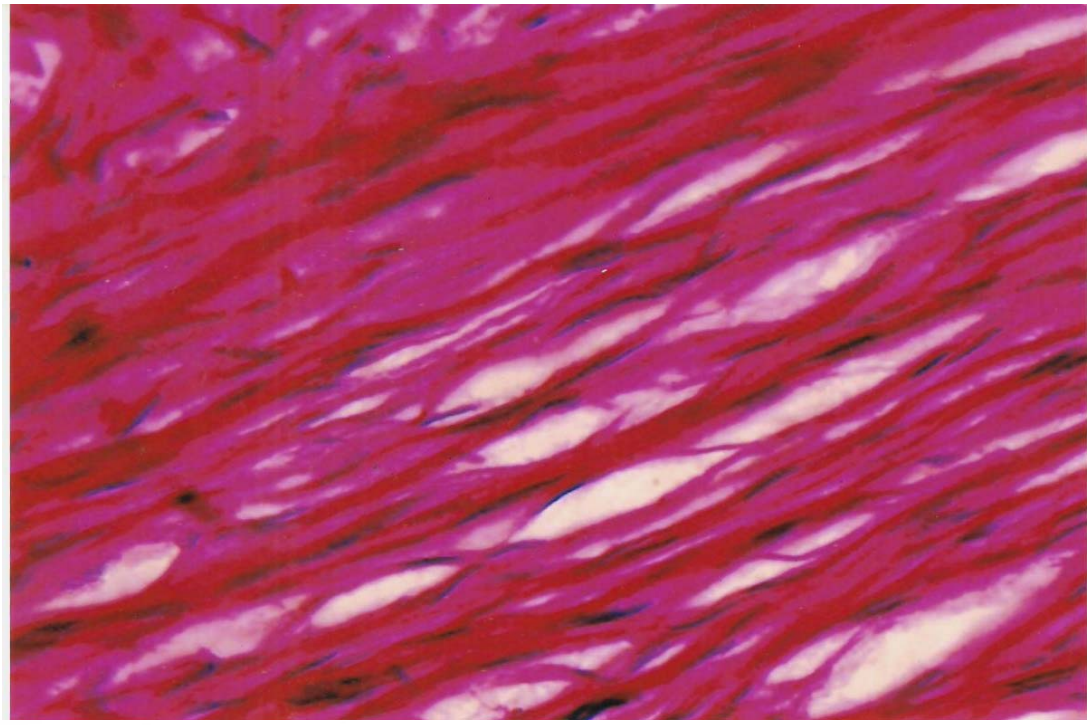

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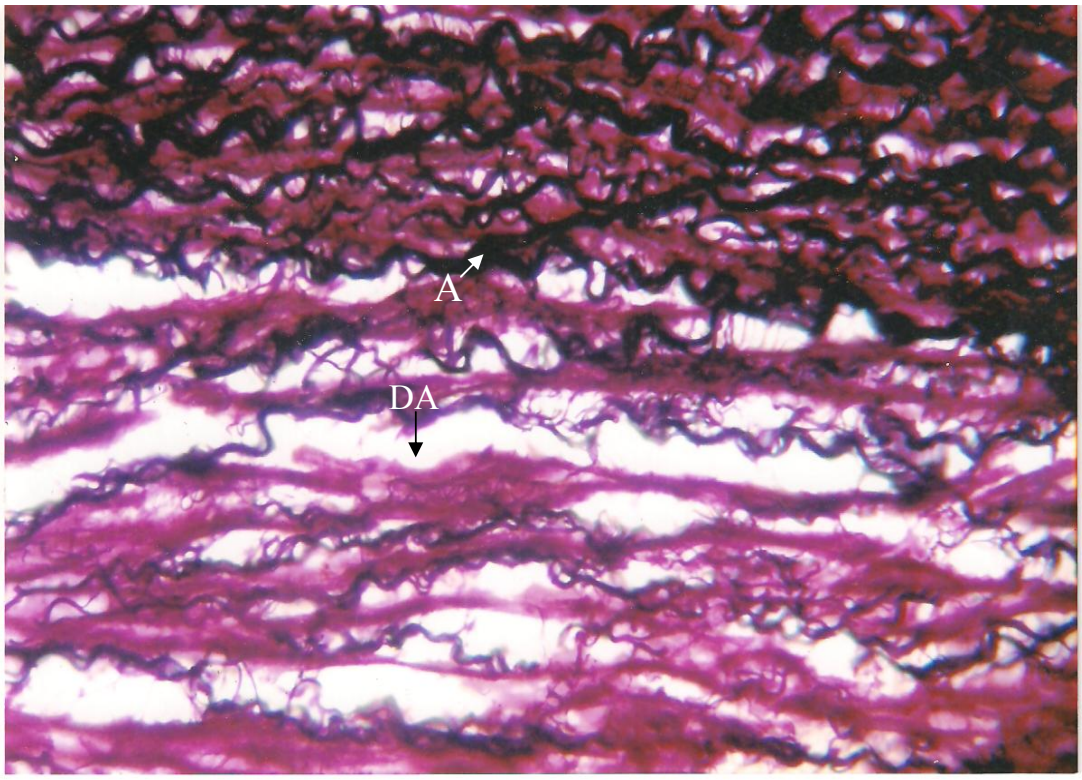
Fig. 47: Photograph of the wall of the ductus arterious (DA) within the aortic wall (A), during third trimester. Note the dense and thick elastic fibres (black) in the aortic wall in comparison to the ductus arteriosus wall. Aldehyde Fuchsin stain. X 1200.

Fig. 48: Photograph of an aortic body demonstrating type I cell (I), type II cell (II) and capillaries (C) in the aortic body during third trimester. Masson´s Trichrome stain. X 1200.



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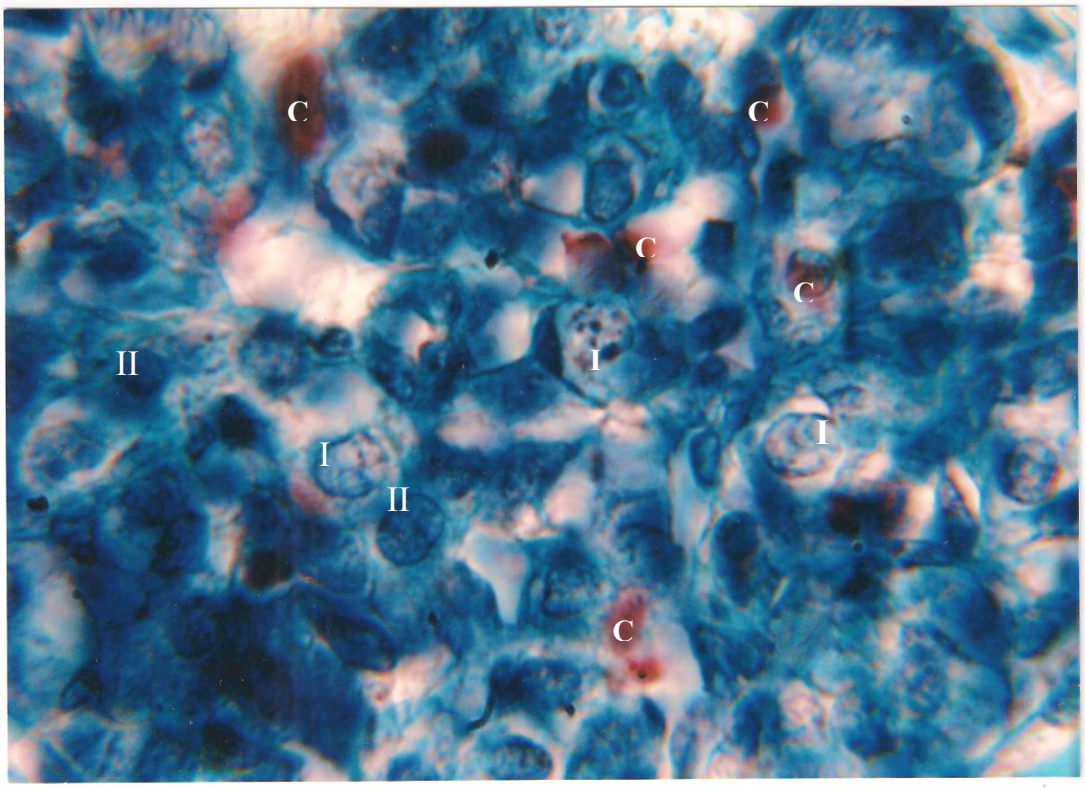
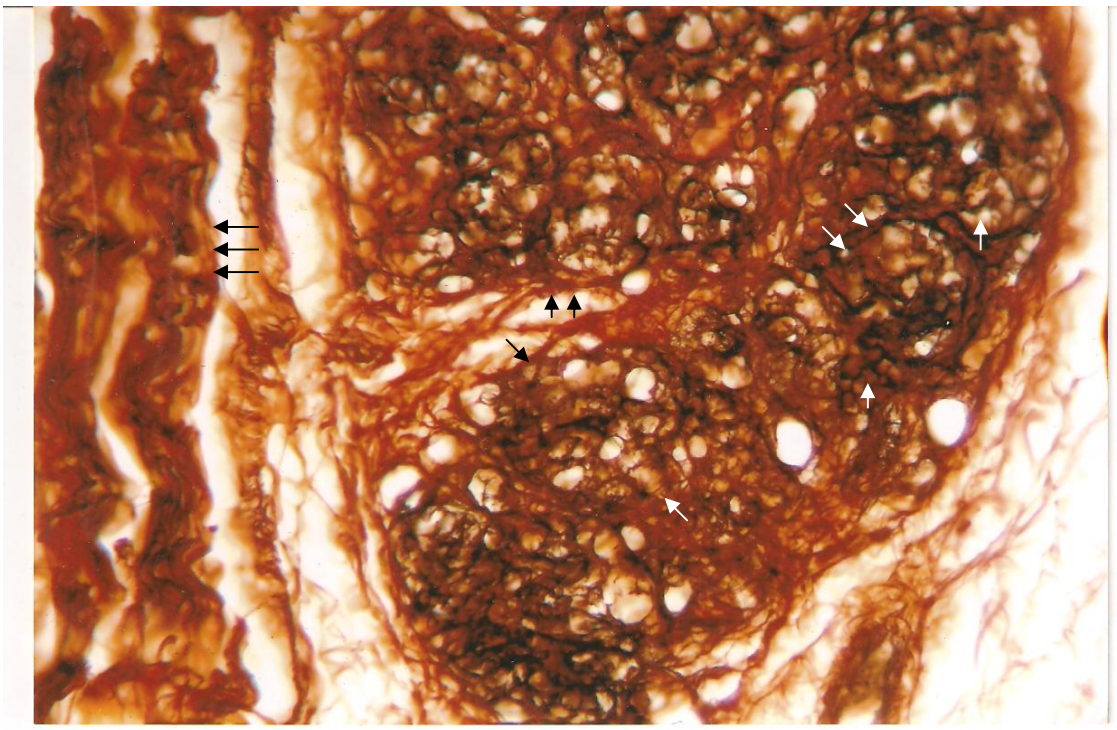


48

Fig. 49: Photograph of a carotid body showing acini (arrow heads), elastic fibres (black) and nerve fibres (arrow), during third trimester. Verhoeff's stain. X 1200

Fig. 50: Photograph of groups of carotid bodies (arrows) near the internal carotid artery (IC) during third trimester. Verhoeff's stain. X 300.



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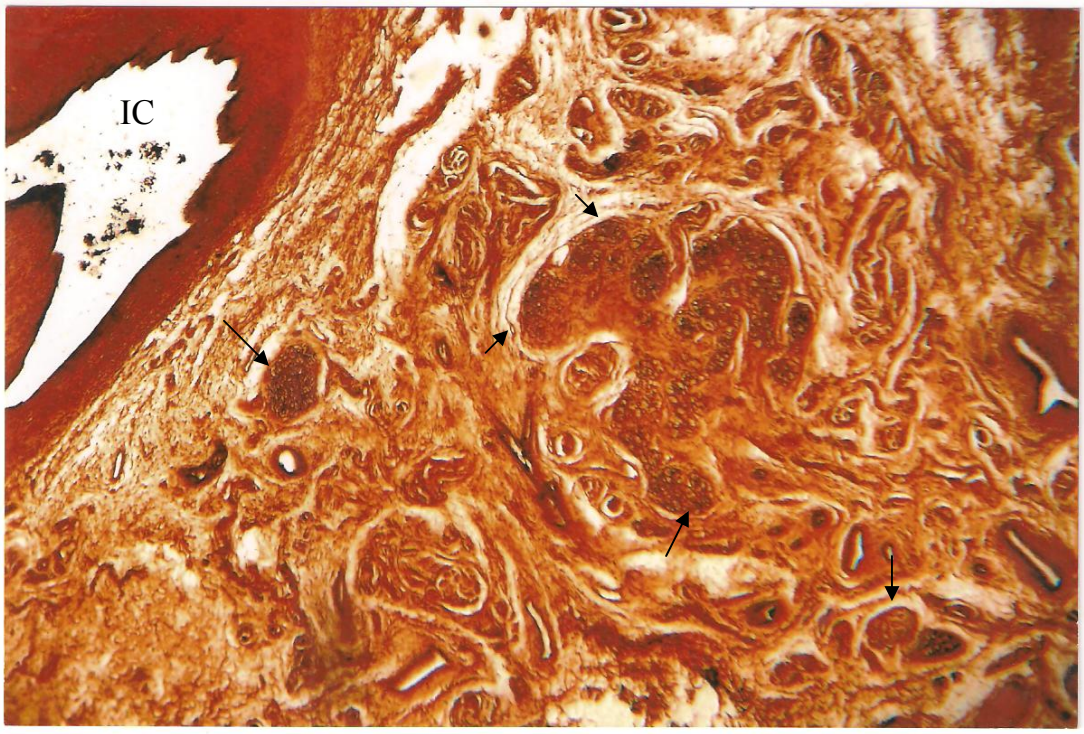

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Fig. 51: Photograph showing a weak PAS-positive diastase resistant material at the bifurcation of common carotid artery (C) to internal carotid artery (I) and external carotid artery (E), during first trimester. PAS technique. X 1200.

Fig. 52: Photograph of an aortic sinus region demonstrating strong PAS-positive diastase digested material during second trimester. PAS technique. X 300.

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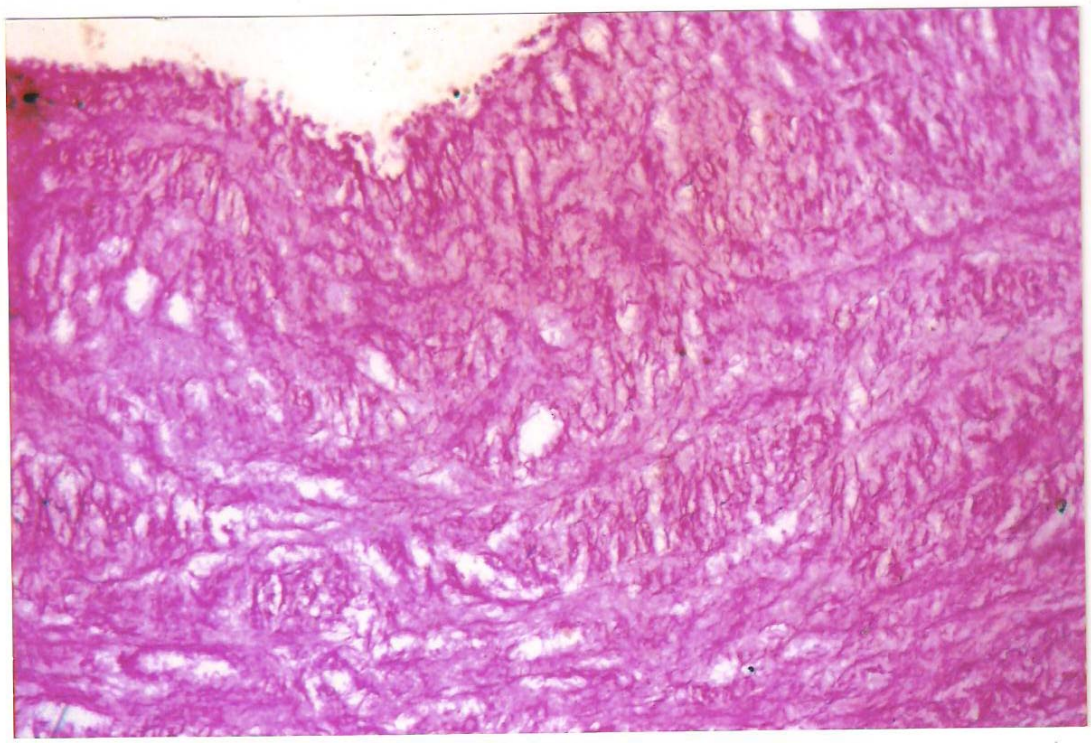

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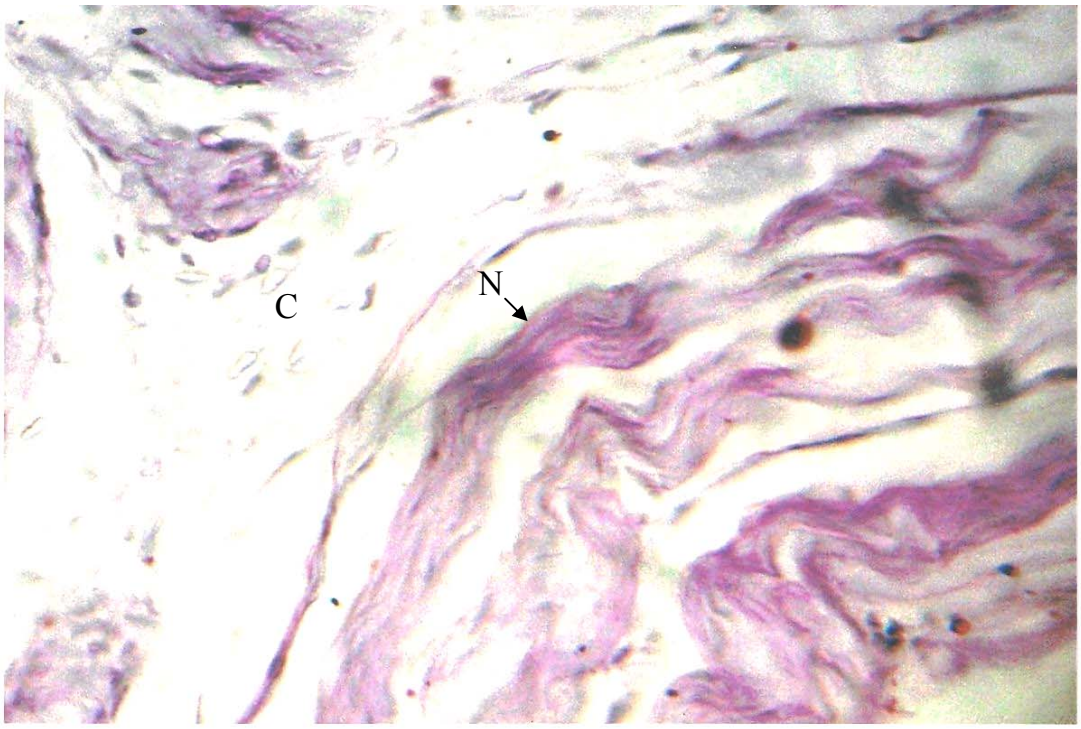
Fig. 53: Photograph showing a weak PAS-positive diastase digested material in the nerve fibres of the carotid body (N) while the connective tissue (C) is negative during second trimester. PAS technique. X 1200.

Fig. 54: Photograph illustrating strong PAS-positive diastase digested material in the carotid body nerve fibres (N), the cellular elements of the body and the endothelial lining of the blood vessels (arrow heads), during second trimester. PAS technique. X 300.



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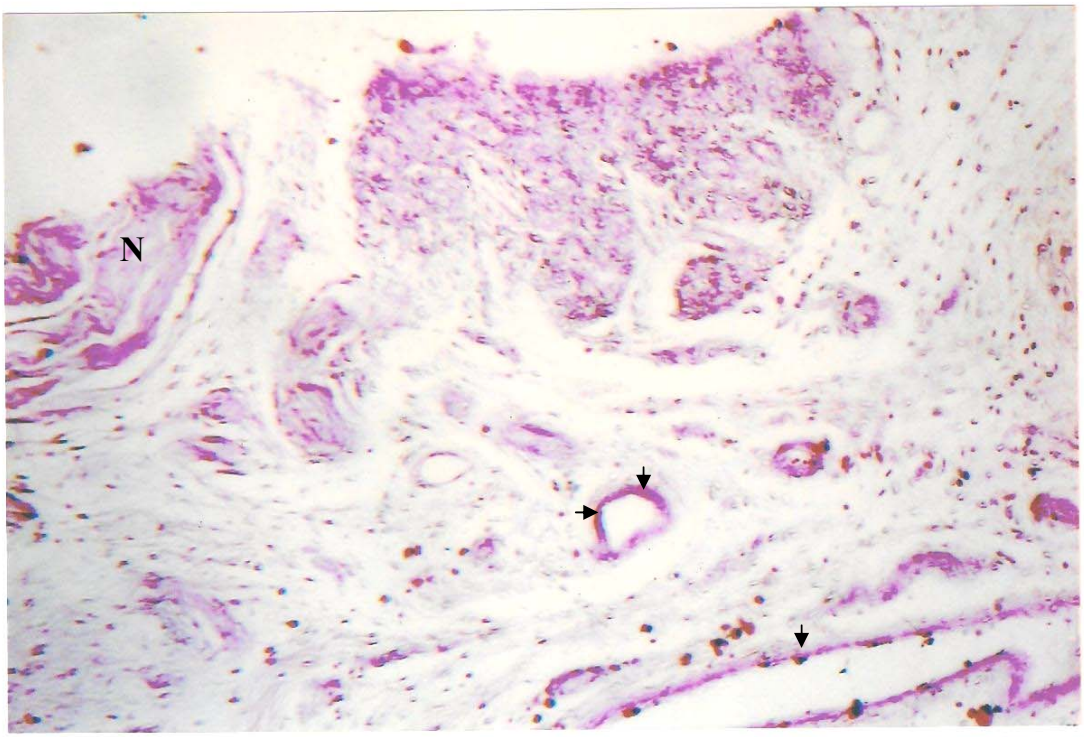

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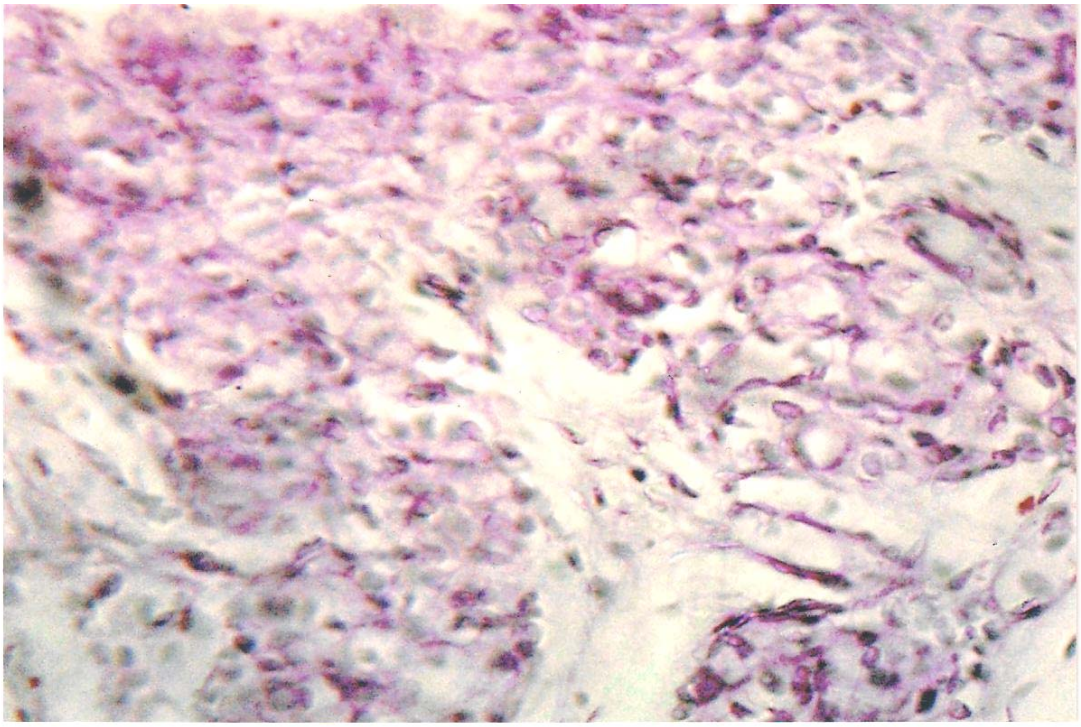
Fig. 55: Photograph showing a PAS-positive diastase digested material in carotid body during second trimester. Note the reaction found in the different part of the aortic body. PAS technique. X 1200.

Fig. 56: Photograph demonstrating PAS-positive digested diastase material in the aortic body during third trimester. Note the reaction in the interstitial tissue and boundary of the acinus-like structure. PAS technique. X 300.



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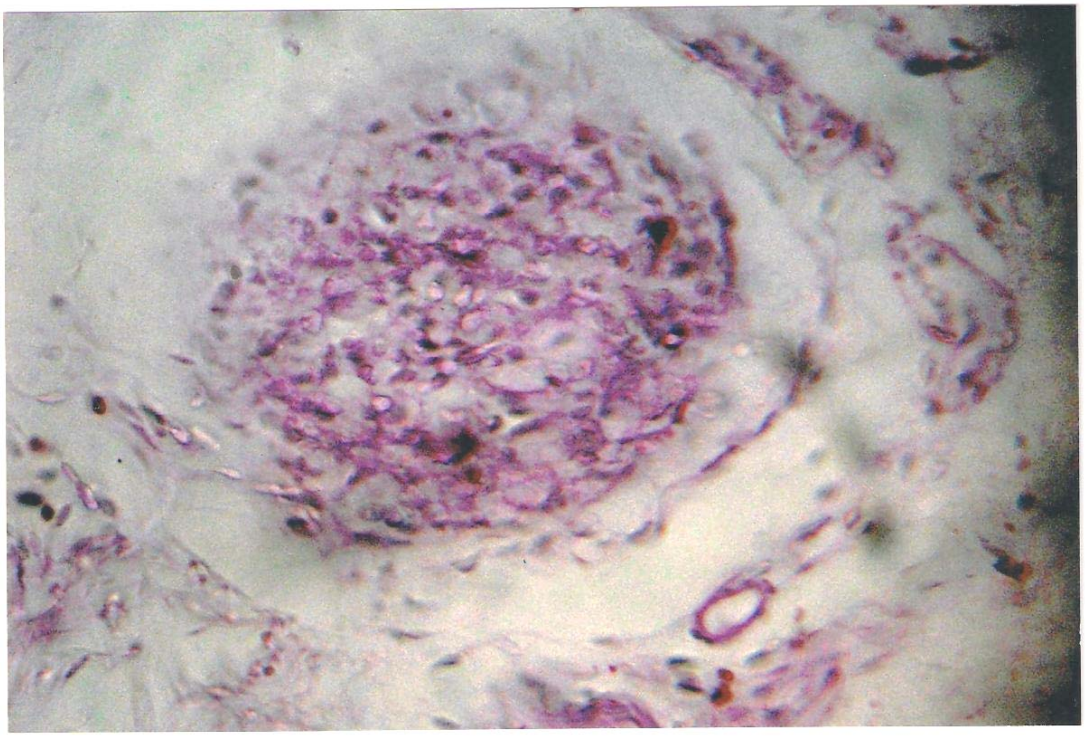
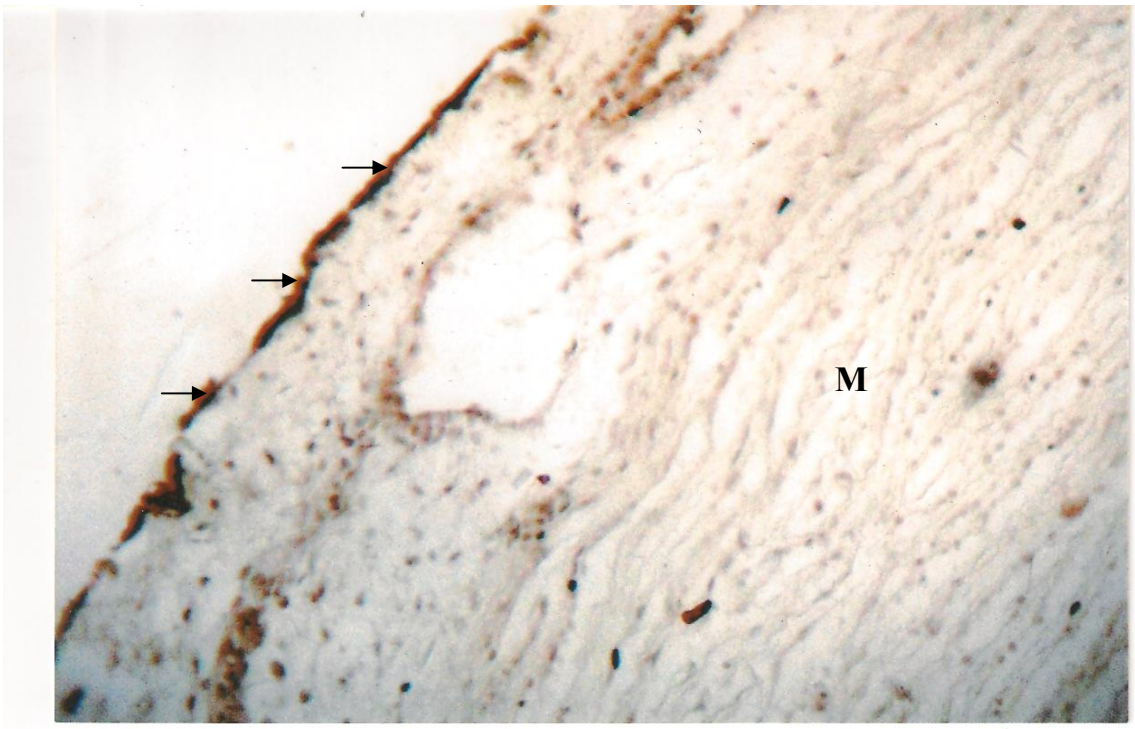


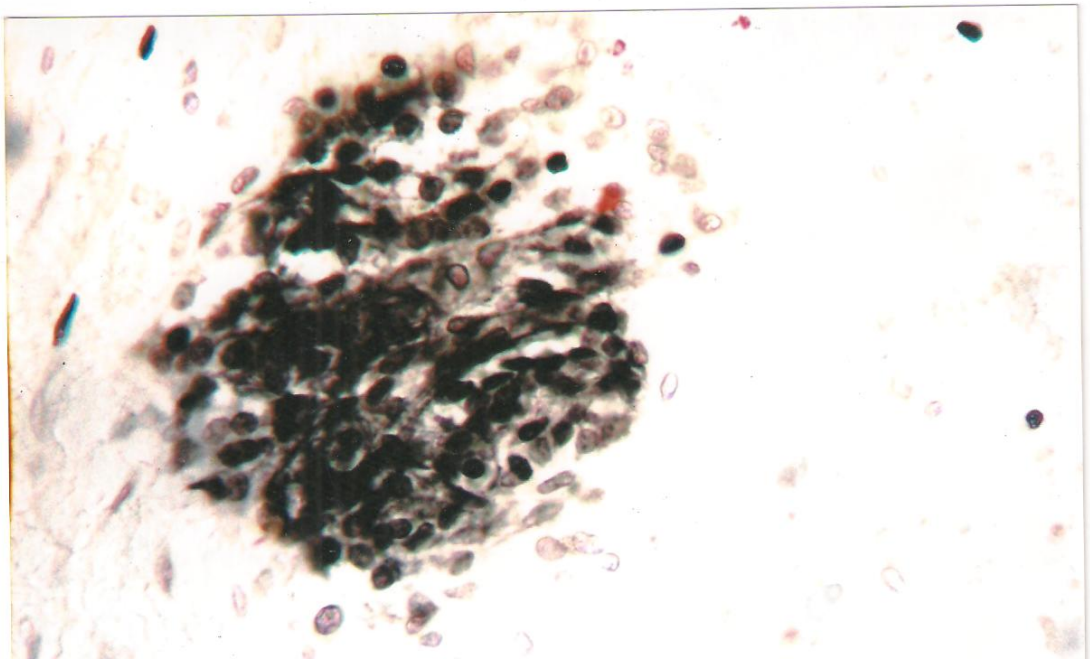
56

Fig. 57: Photograph demonstrating alkaline phosophatase activity (dark brown) in the outer part of the adventitia of an aortic sinus (arrows) while the tunica media (M) is negative during second trimester. Gomori and Lillie technique. X 300.

Fig. 58: Photograph illustrating strong alkaline phosphatase activity in an aortic body during second trimester. Gomori and Lillie technique. X 1200.



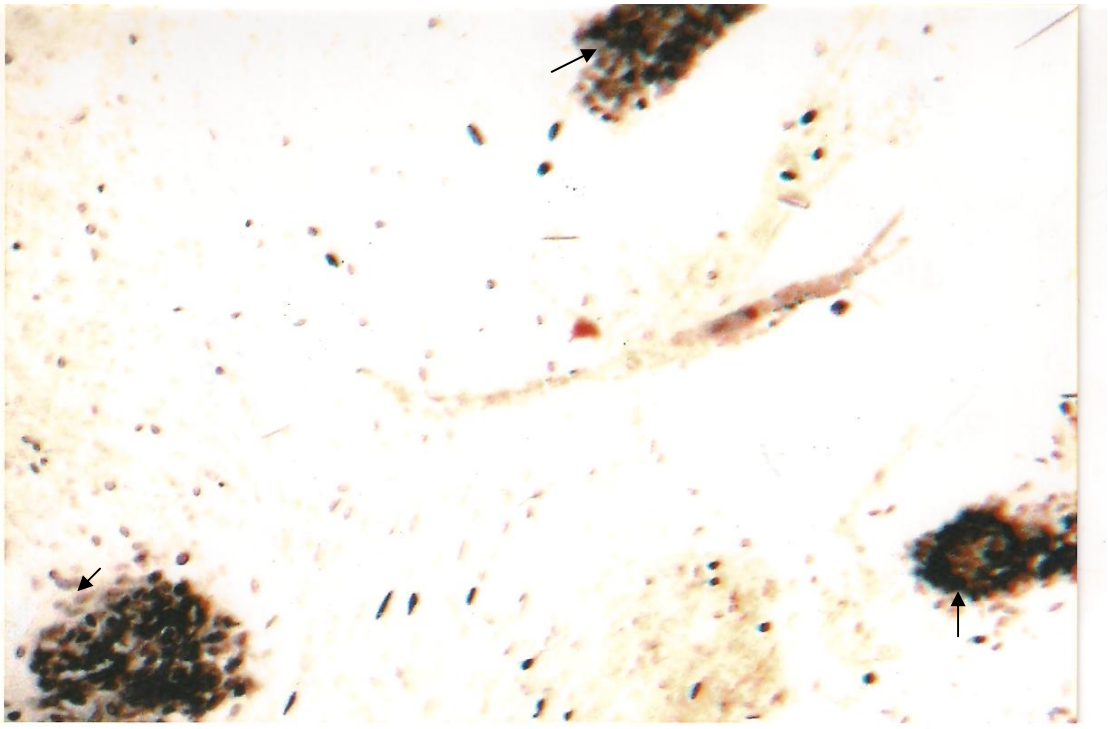
57



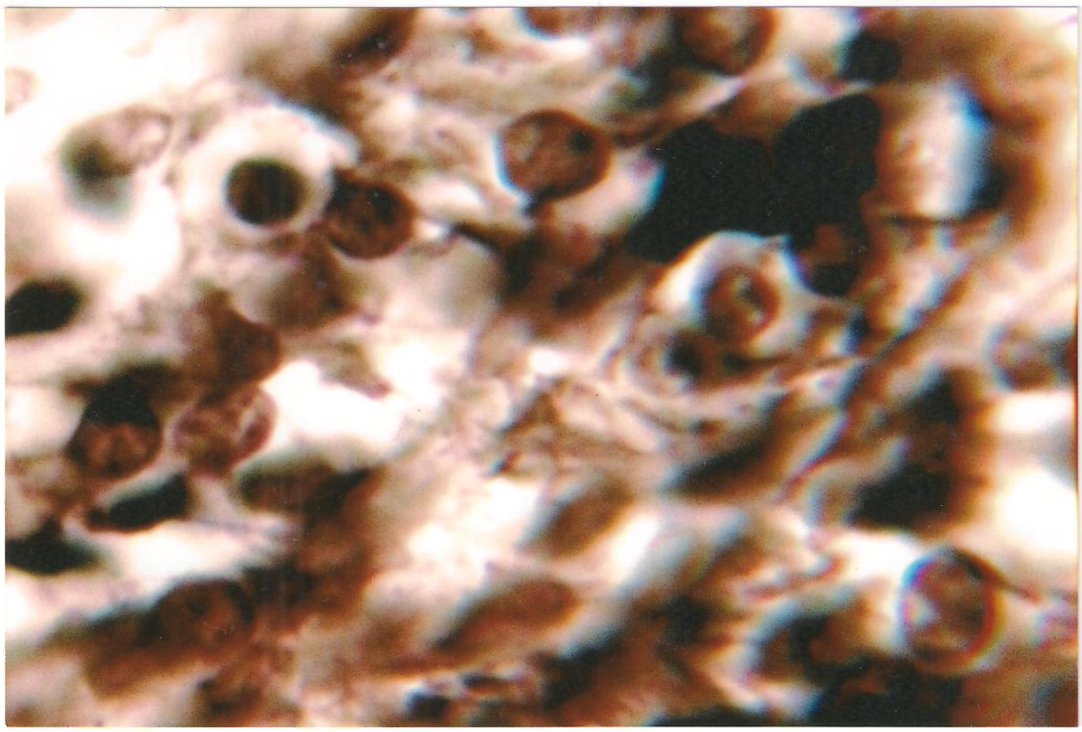
58

Fig. 59: Photograph demonstrating alkaline phosphatase activity in the aortic bodies (arrows) during second trimester. Gomori and Lillie technique. X 300.

Fig. 60: Photograph of higher magnification from figure (59) showing alkaline phosphatase activity in the interstitial tissue around the cells of the aortic body, during second trimester. Gomori and Lillie technique. X 3000.



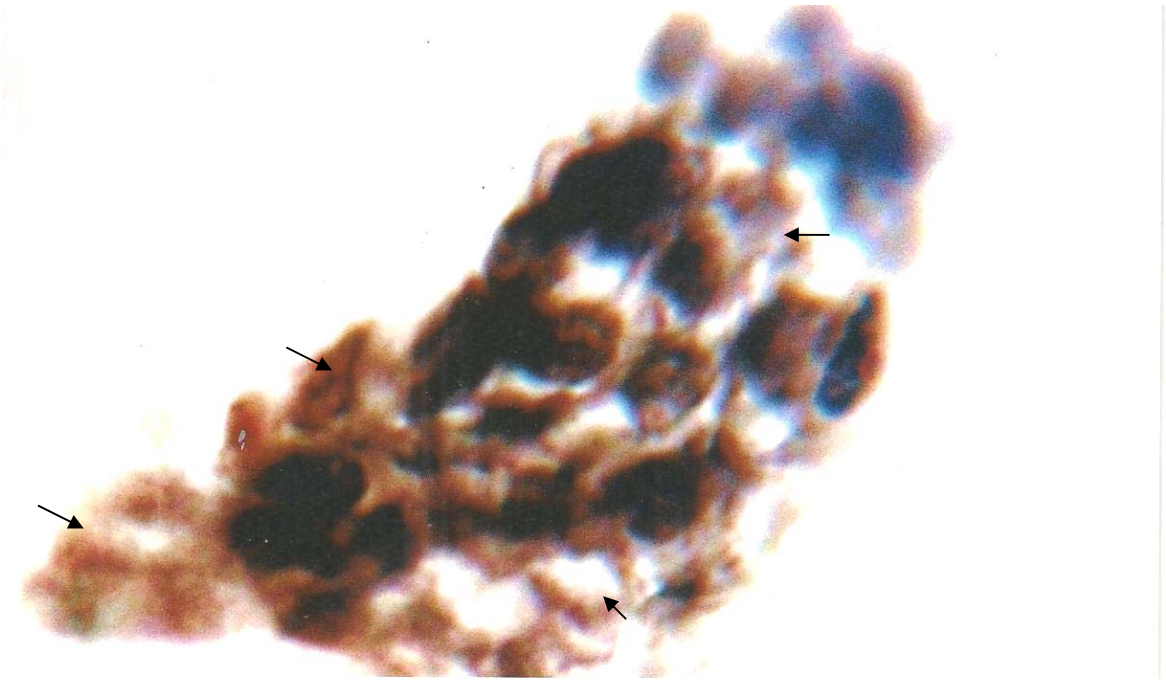
59



60

Fig. 61: Photograph showing alkaline phosophatase activity in the interstitial tissue of carotid body around the type I and type II cells (arrows) during second trimester. Gomori and Lillie technique. X 3000.

Fig. 62: Photograph demonstrating a strong acid phosphatase activity in the lining epithelium of the aortic sinus during first trimester. Modified Gomori technique. X 1200.



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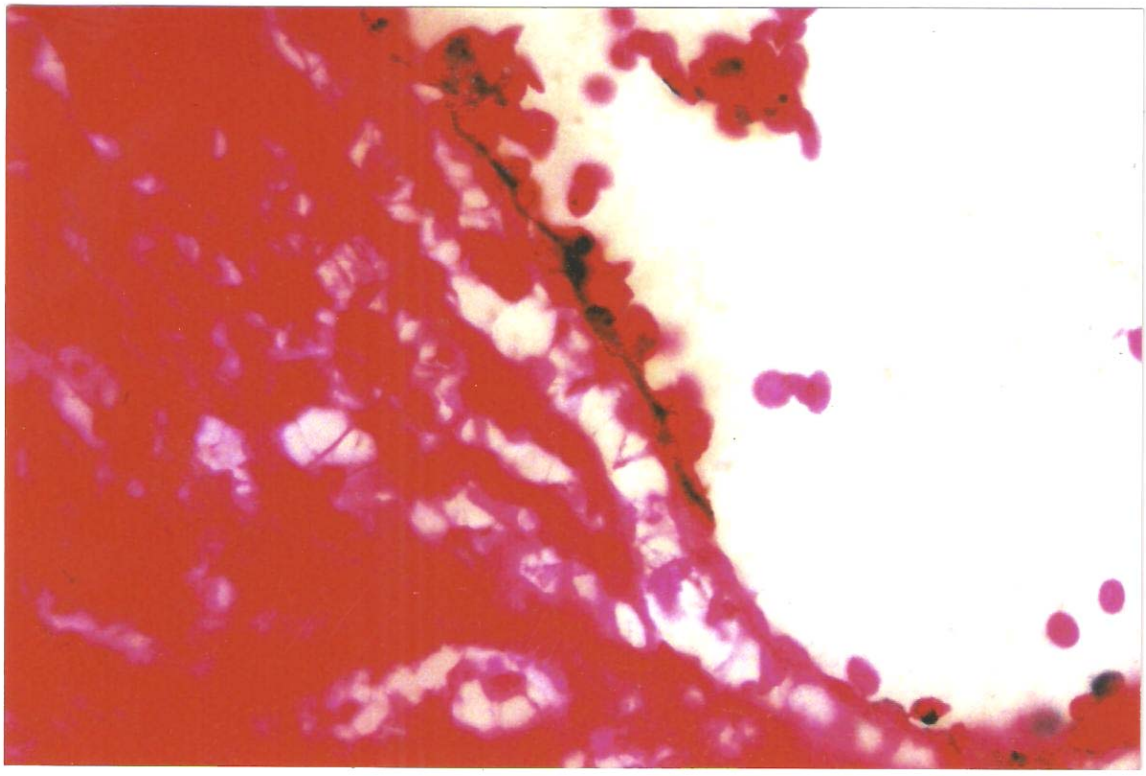
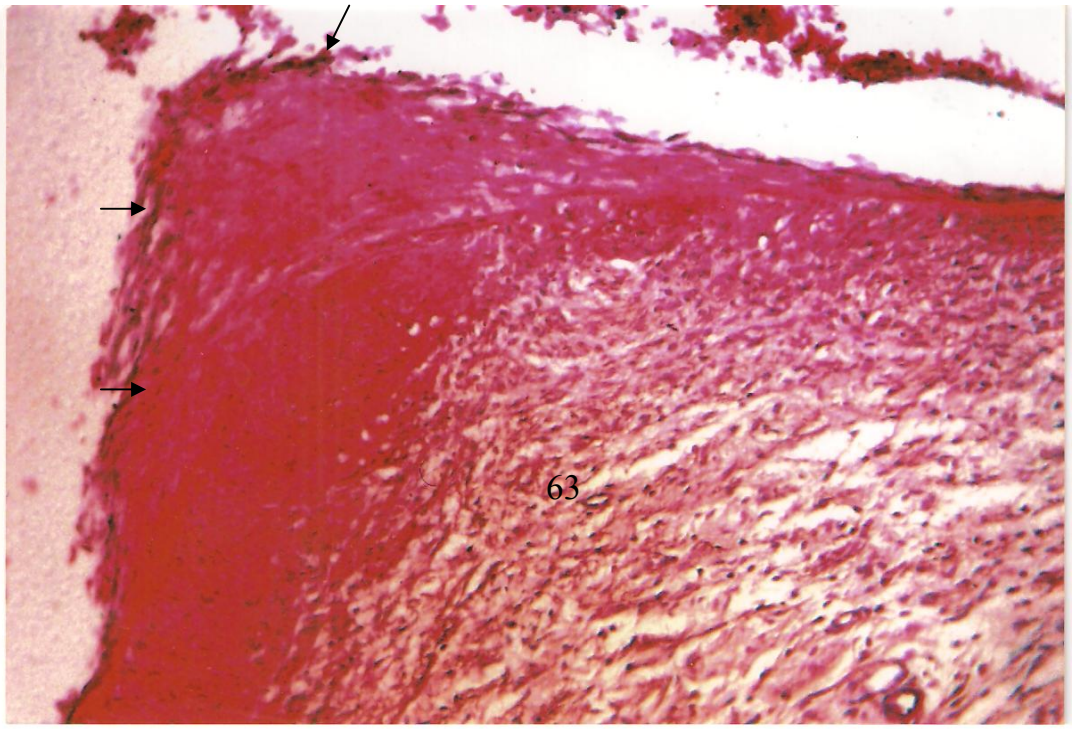


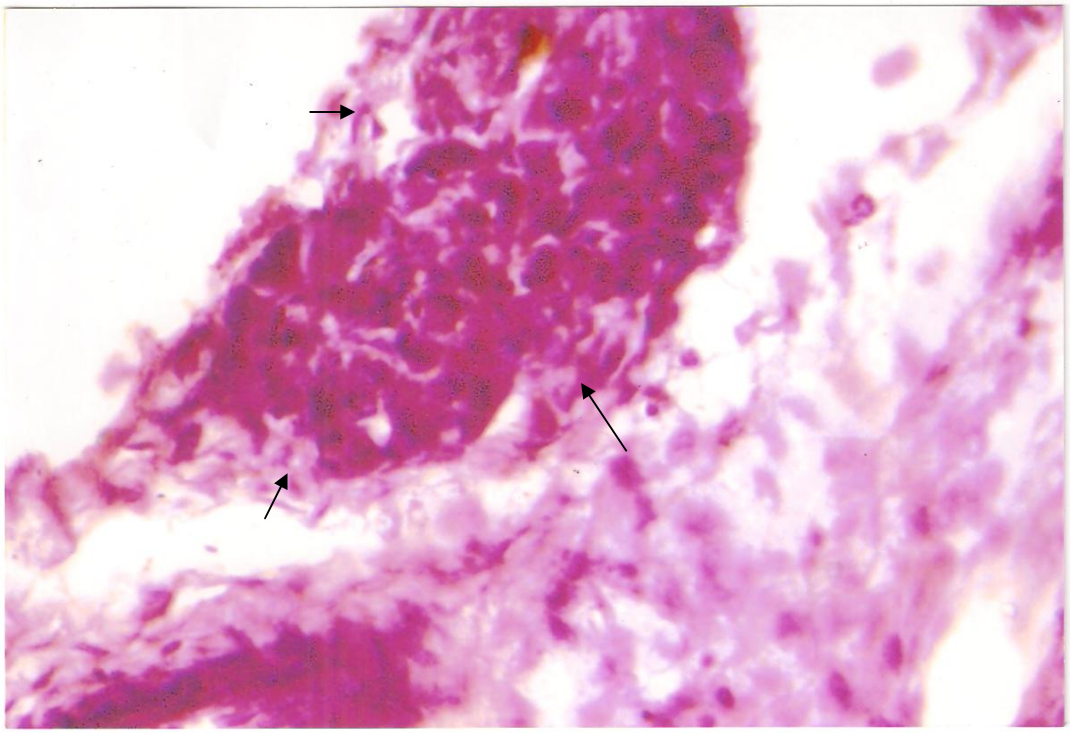
62

Fig. 63: Photograph showing strong acid phosophatase activity in the lining epithelium of carotid sinus (arrows) during third trimester. Modified Gomori technique. X 300

Fig. 64: Photograph demonstrating a weak acid phosphatase activity in the carotid body (arrows) during first trimester. Modified Gomori technique. X 1200.

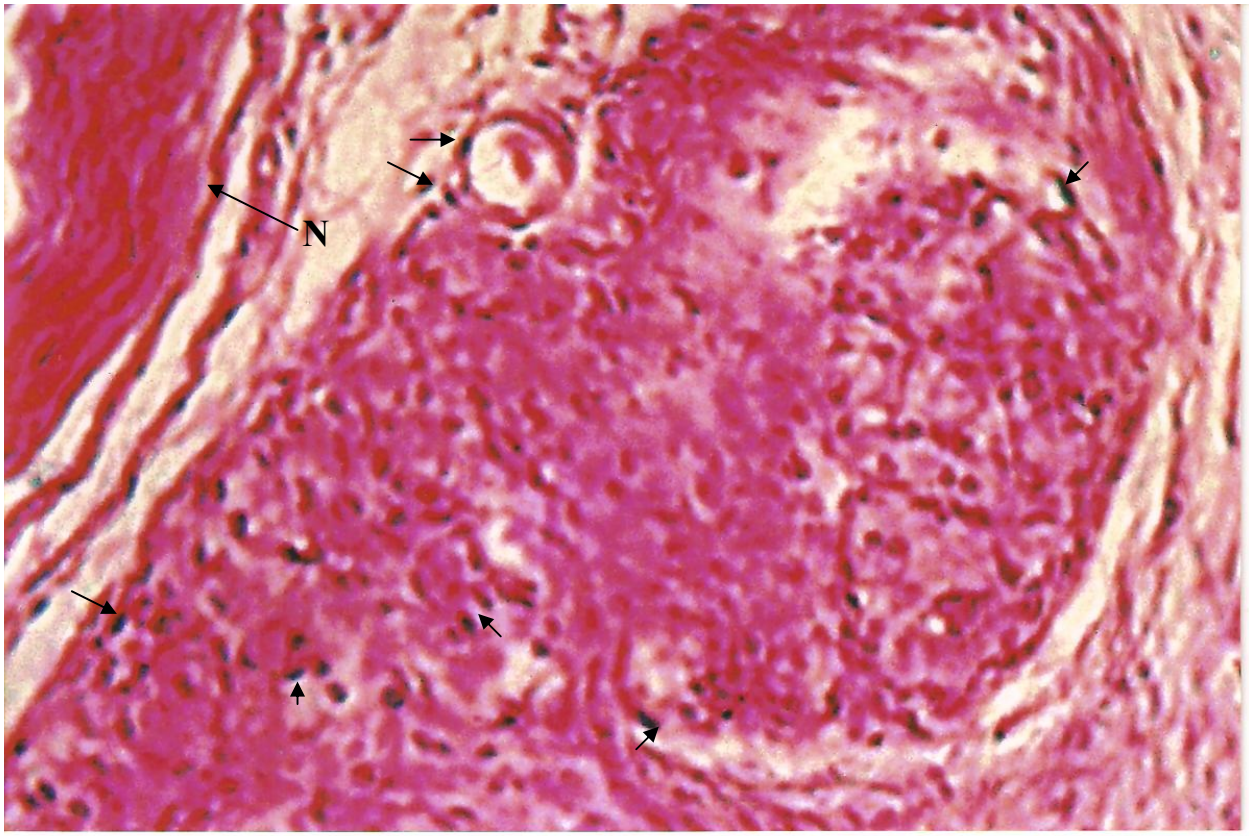


63



64

Fig. 65: Photograph illustrating acid phosphatase activity in a carotid body. Note that the reaction is scattered in the body (arrows) and in the nerve fibres (N) during second trimester. Modified Gomori technique. X 300.



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